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WASTEWATER TREATMENT PLANT ENVIRONMENTAL STUDY, MACDILL AFB, FL

ARMSTRONG LABORATORY

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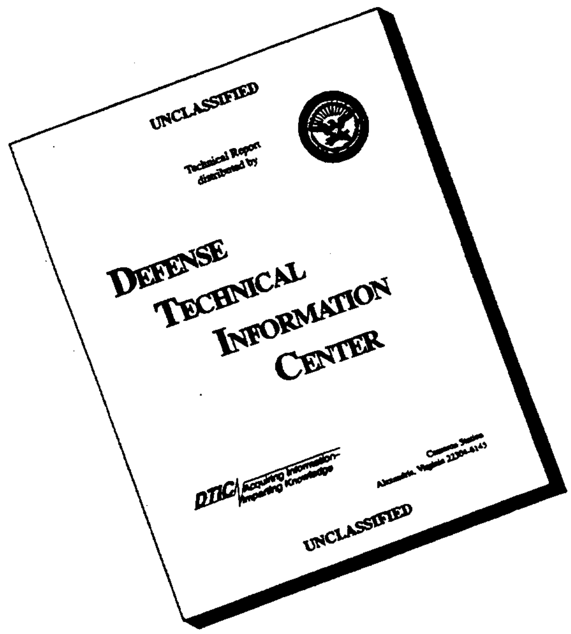

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The Final Operations and Maintenance Manual for the MacDill Air Force Base provides necessary information for successfully operating the installation wastewater treatment plant including descriptions of fundamental concept related to the facility. The O&M Manual acquaints personnel with overall capabilities of the plant, instruction on the purpose and intended operation of each unit process and instruction on the proper operation and maintenance of the facility. Manual chapters include Facility Description, Theory of Unit Processes, Sampling and Analytical Schedule, Laboratory Testing, Safety, Maintenance, Standard Operating Procedures, Records and Reports, and Nondomestic Discharges.

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TABLE OF CONTENTS

TABLE OF CONTENTS
(CONTINUED)

TABLE OF CONTENTS
(CONTINUED)

TABLE OF CONTENTS
(CONTINUED)

TABLE OF CONTENTS
(CONTINUED)

TABLE OF CONTENTS
(CONTINUED)

TABLE OF CONTENTS
(CONTINUED)

TABLE OF CONTENTS
(CONTINUED)

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES
(CONTINUED)

CHAPTER 1
INTRODUCTION TO THE MACDILL AIR FORCE BASE WASTEWATER TREATMENT SYSTEM

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INTRODUCTION TO THE MACDILL AIR FORCE BASE WASTEWATER TREATMENT SYSTEM

1.1 INTRODUCTION

This volume has been prepared for the operations and maintenance staff for the purpose of successfully operating the MacDill Air Force Base wastewater treatment plant (WWTP). This manual is intended to serve both as a training resource and as a routinely used guide to assist in the day-to-day operation and maintenance of the treatment facility.

The specific purpose of this manual is to provide the information necessary for plant personnel to make proper decisions that will ensure successful operation of the plant. This manual fulfills this goal by: (1) acquainting personnel with the overall capabilities of the equipment; (2) instructing them on the purpose and intended operation of each process; and (3) providing them with the necessary instructions for the proper operation and maintenance of the facility.

The chapters of the O&M Manual are an attempt to provide complete and straightforward descriptions of the fundamental concepts related to the treatment facility. It is hoped that through frequent and routine use of the manual, plant personnel will become thoroughly familiar with the fundamentals presented and will be able to identify problems and determine a course of action for their solution. No manual, however complete and well prepared, can replace good judgment on the part of plant personnel in ensuring successful operation of the wastewater treatment facility. There are far too many possible problems and situations that the operations and maintenance staff will have to face for any such document to cover them all in detail.

The organization of this material is intended to make it easy to find desired information and keep it up to date. The format and use of a numerical outline will allow selected portions of the manual to be easily revised and updated. New chapters can be added or existing chapters expanded without affecting the remainder of the document. No manual written without the benefit of actual operating experience and input from the plant operators will be either complete or entirely correct. It is hoped that these chapters will be periodically updated to keep them current and maintain their usefulness. Review and comments from the plant operating personnel are essential to the usefulness of the O&M manual.

Operators should also utilize other resources available to them when making operational decisions. These include plans and specifications, vendor supplied materials, and relevant training materials. References to these materials will be made throughout the O&M manual.

1.2 GENERAL PROCESS DESCRIPTION

The MacDill AFB wastewater treatment plant is a biological treatment system employing the activated sludge process and filtration to achieve tertiary treatment levels. The plant employs preliminary and secondary treatment processes, tertiary effluent filtration, and anaerobic sludge digestion. The treatment plant is designed to treat an average daily wastewater flow of 1.2 million gallons per day (MGD). The treatment plant's most recent major modification was completed in March 1995.

1.2.1 Major Treatment Units

The major treatment units at the MacDill AFB wastewater treatment plant are:

- Screening
- Grit Removal
- Equalization
- Biological Treatment (Activated Sludge)
- Secondary Clarification
- Tertiary Filtration
- Disinfection
- Effluent Spray Irrigation
- Anaerobic Sludge Digestion
- Sludge Land Application

Figure 1.1 presents a flow schematic of the MacDill AFB wastewater treatment plant. Major plant unit processes and flow streams are identified in the schematic.

In addition to the wastewater treatment plant and laboratory, the Operations and Maintenance personnel are responsible for 2 water booster stations, 2 ground storage tanks, 2 elevated storage tanks, grounds and building maintenance, 2 package plants, disposal of trash from arriving overseas aircraft, and 50 lift stations. For six months of the year the WWTP staff is also responsible for the operation and maintenance of the two base swimming pools. The fifty (50) lift stations are located mainly on the eastern half of MacDill AFB. These lift stations are identified in Table 1.1.

MACDILL AFB WWTP FLOW SCHEMATIC

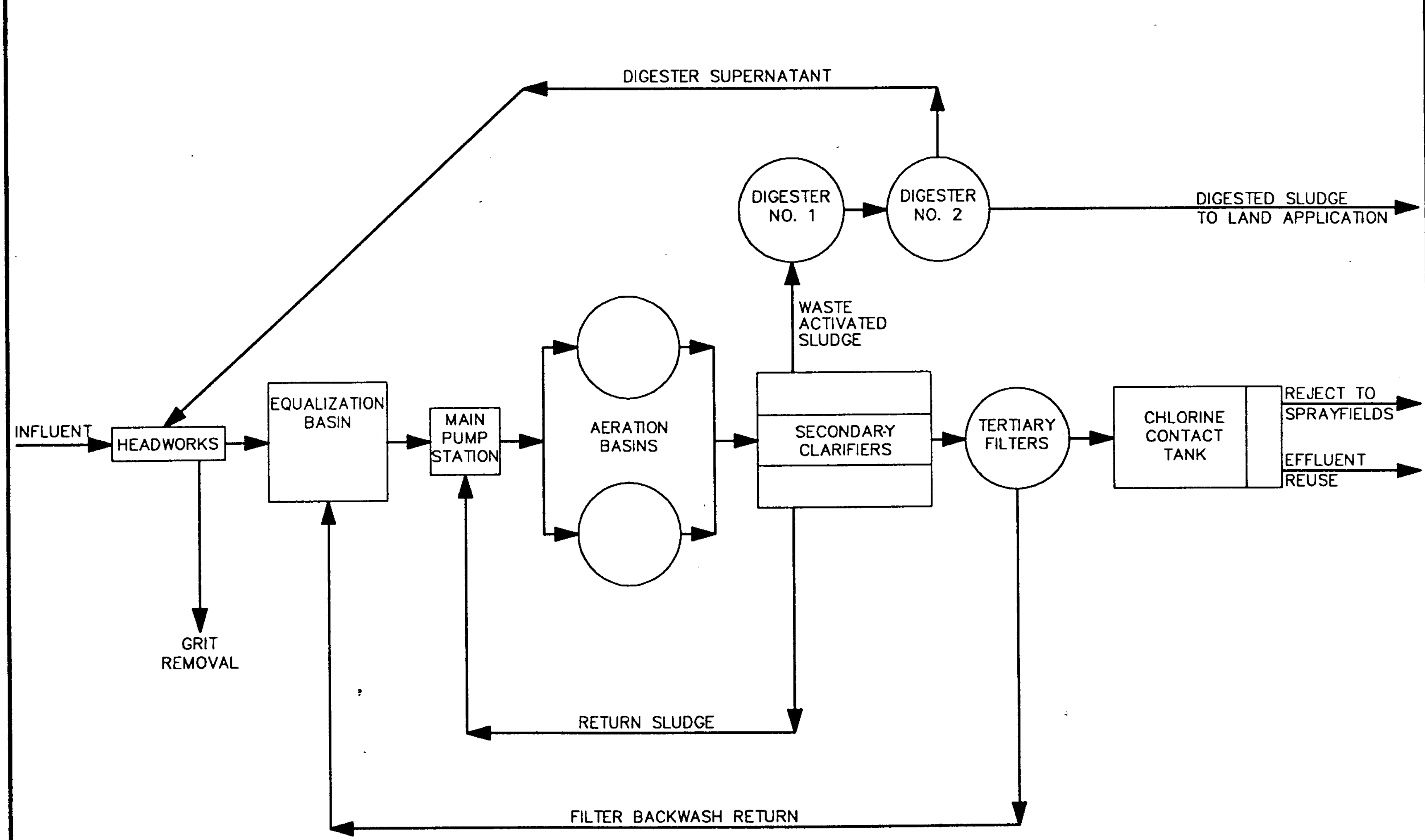

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Figure 1.1

Table 1.1 - Lift Stations

NAME/NUMBER	PUMP LAYOUT	LOCATION/COMMENTS
DRMO pkg plant	Simplex	DRMO; 2.8 hp
DRMO pkg plant	Simplex	DRMO; 2.8 hp
DRMO pkg plant	Simplex	DRMO; 2.8 hp
Entomology	Duplex	Entomology; to drainfield
Hanger 4	Simplex	Hanger 4
Hospital Supply	Duplex	Hospital supply
Hush House	Simplex	Hush house
Hush House	Simplex	Hush house
Hush House	Simplex	Hush house
P8	Simplex	Wash rack
Pavillion	Duplex	Pavillion; family camp area
Pistol Range	Duplex	Pistol range
Zone 1	Simplex	NW corner of Base (Zone 1)
21	Triplex	Across from BOQ; generator
22	Duplex	Redcom parking lot; bar screen
39	Duplex	Flight line, near Bldg 48
49	Simplex	Flight line, Bldg 49
62	Duplex	Front of hospital
69	Duplex	Flight line (old tower)
70	Simplex	E of Bldg 69 on corner of flight line
73	Duplex	Marina trailer park
78	Duplex	Adjacent to JCSE (ammo area)
86	Duplex	Inside radar site
185	Duplex	Flight line
194	Duplex	Flight line
354	Simplex	Next to housing referral
518	Simplex	Flight line wash rack; o/w separator
552	Simplex	Flight line; o/w separator

Table 1.1 - Lift Stations (Cont'd.)

NAME/NUMBER	PUMP LAYOUT	LOCATION/COMMENTS
Zone 610	Duplex	Front of Bldg. 717
633	Duplex	Enlisted housing area; generator; bar screen
696	Duplex	Next to hospital supply
698	Simplex	Family camp area
699	Duplex	Golf course club house
705	Duplex	Base mobile home park, west
706	Duplex	Base mobile home park, east
717	Duplex	Bldg 717 near WWTP
718	Duplex	Road to retention pond
822	Duplex	Ammo storage area
844	Duplex	Past sanitary landfill
869	Duplex	Officers housing area (20 homes)
932	Duplex	Burger King
970	Duplex	Champus office
1063	Duplex	Flight line behind commissary; o/w separator
1065	Duplex	N of apron taxi way; o/w separator
1106	Duplex	(Old pkg. Plant #1106), pumps to #844
1144	Simplex	N of apron taxi way; o/w separator
1148	Simplex	Mole hole area
1161	Simplex	North of control tower; to drainfield
1873	Duplex	Family camp area
1887	Duplex	
2017	Duplex	Marina

The seven major lift stations are No. 21, No. 22, No. 62, No. 633, No. 705, No. 706 and No. 718.

1.3 OPERATOR AND MANAGEMENT RESPONSIBILITY

1.3.1 Operator Responsibility

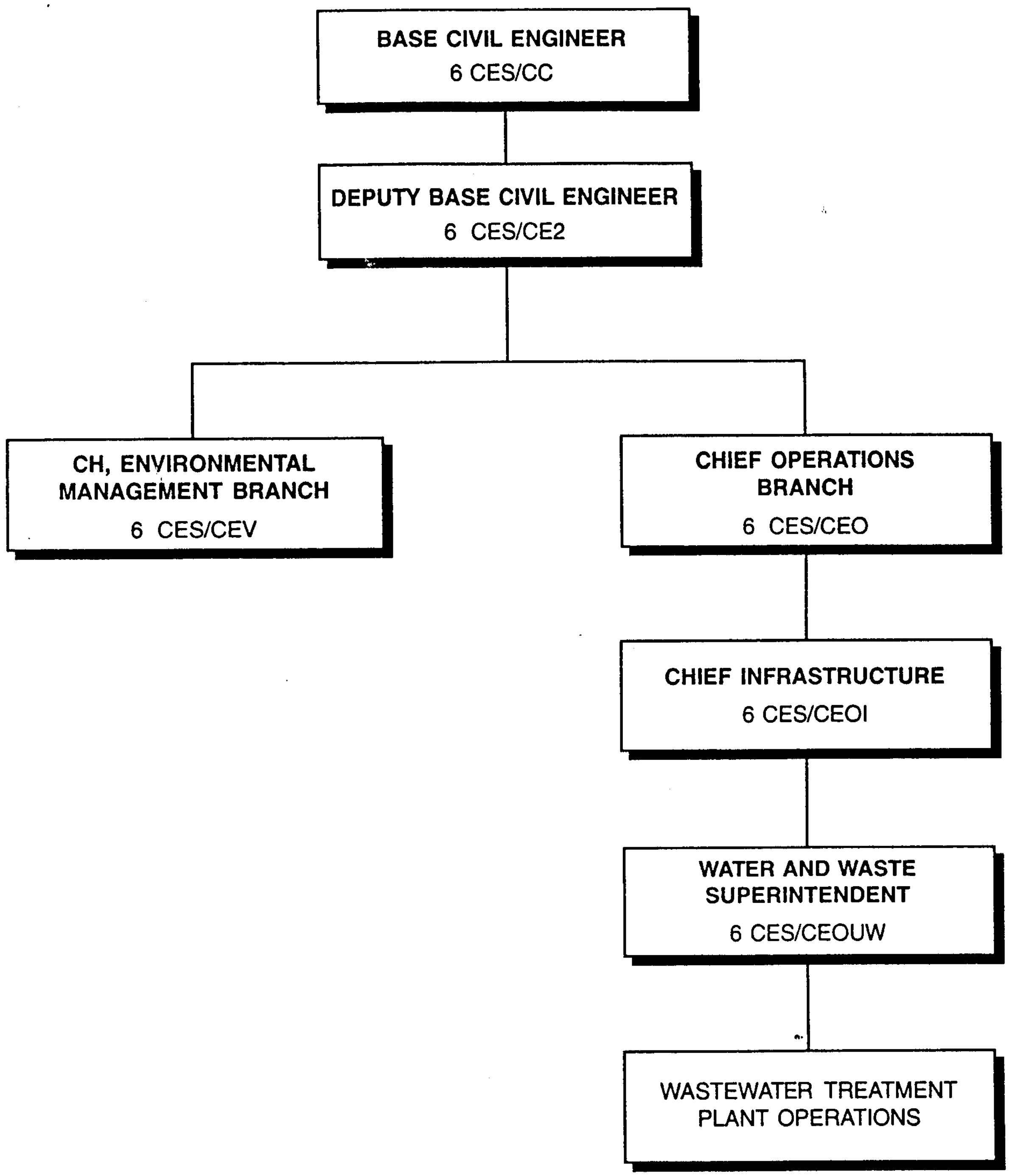
Great sums of public funds have been invested in many large and complex wastewater treatment facilities to meet the discharge requirements necessary to maintain and protect the environment. Because of their function, the wastewater treatment plant operators play a key role in pollution control. Without efficient operation of each facility, the research, planning, and construction that has been done to accomplish the goals of water quality control will be wasted. Thus, the treatment plant operator can make the difference between pollution control equipment which is performing just adequately or excellently. Operators have a very responsible and important position since they are the only ones who control how well the wastewater will be treated before it is discharged into the environment.

The MacDill AFB operators are responsible for the overall operation and maintenance of the WWTP. Their duties encompass all activities of the WWTP and in other areas, such as lift stations, swimming pools and potable water storage and pumping.

1.3.2 Management Responsibility

Management of the MacDill AFB wastewater plant, including Base Civil Engineer and Deputy Engineer, the Chief of the Operations Branch of the Civil Engineering Squadron and Wastewater Superintendent have responsibility for providing administrative and supervisory control over the operation and maintenance of the treatment system. These responsibilities include supervisory direction, personnel management, and coordination with other on-base support services. Management is also responsible for ensuring effective communication among all personnel, encouraging operational suggestions, and marshaling the necessary resources for needed projects at the WWTP. Figure 1.2 provides an organization chart for the MacDill AFB WWTP.

MACDILL AFB WWTP ORGANIZATIONAL CHART



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1.4 Operator Training and Selected Reference Materials

There are no formal training programs available for the operators at the MacDill AFB WWTP. On-the-job training is the primary training mechanism used.

To enhance a self-study program, a number of more advanced materials specific to the MacDill AFB wastewater treatment plant should be obtained for use by the operators. Recommended references from the Water Environment Federation and the Air Force include:

- Sacramento Course - Operation of Wastewater Treatment Plants, Volumes 1 and 2.
- Sacramento Course - Industrial Waste Treatment
- Air Force Manual AFM 91-32 - Operation and Maintenance of Domestic and Industrial Wastewater Systems
- Standard Methods for the Examination of Water and Wastewater, 18th Edition
- Manual of Practice OM-9 - Operation and Maintenance of Activated Sludge Plants
- Manual of Practice 7 - Operation and Maintenance of Wastewater Collection Systems
- Manual of Practice OM-3 - Plant Maintenance Program
- Manual of Practice 11 - Operation of Wastewater Treatment Plants
- Manual of Practice OM-1 - Wastewater Sampling for Process and Quality Control

In addition to the above self-study materials, it is recommended that the following approaches to operator training be adopted at the MacDill AFB wastewater treatment plant:

- An in-house training program utilizing plant personnel and base resources focused on specific plant processes and treatment-related subjects should be adopted. Classes should be held on at least a monthly basis.
- Attendance at outside training schools or training courses provided by outside trainers should be encouraged to the extent possible within budget constraints.
- Informal group study sessions among the operators during shift hours should be encouraged to promote discussion and interest in the operation of the wastewater plant.
- Within budget constraints, operators should participate in correspondence course training offered by California State University at Sacramento.

As an additional aspect of the training program, the wastewater operators should have access to various periodicals pertaining to wastewater treatment. Among the recommended periodicals are:

- Operations Forum, a publication of the Professional Wastewater Operations Division of the Water Environment Federation.
- Water Environment and Technology.

1.5 PERMITS

The MacDill AFB WWTP is designed to be in compliance with the Florida Department of Environmental Protection Domestic Wastewater Treatment Plant Operations Permit (DO29-222584), which expires January 1, 1998. The MacDill AFB WWTP discharges to a reclaimed water holding pond and golf course holding pond then to irrigation on two base golf courses and a spray irrigation field. The Permit discharge limitations are presented in Table 1.2.

Table 1.2
MacDill AFB WWTP
Reclaimed Water Permit Limitations

Parameter	Units	Minimum	Maximum
Flow	MGD		1.2
pH	Std. Units	6.0	8.5
CBOD	mg/l		20 annual avg.
CBOD	mg/l		30 monthly avg.
CBOD	mg/l		45 weekly avg.
Nitrate	mg/l		12.0
Chlorine	mg/l	1.0	
Total Suspended Solids	mg/l		5.0
Fecal Coliform Bacteria	#/100 ml	Non-detect (75% of samples)	25

In addition to the limitations presented in Table 1.2, important operating requirements which should be followed are summarized below:

1. The water quality standards for Class G-II groundwater shall not be exceeded at the boundary of the zone of discharge.
2. The required certified operator and on-site time is a Class C or higher operator, 16 hours per day, seven days per week. The lead chief operator must be Class B or higher.
3. The plant influent must be monitored biweekly and reported monthly along with effluent data on DEP Form 62-601.900(1) (formerly 17-601.900(1)) to the local Southwest District Office of the Department of Environmental Protection and the Environmental Protection Commission of Hillsborough County.
4. The permittee shall monitor the effluent turbidity before disinfection and monitor total chlorine residual after disinfection and before pumping to the reclaimed water system storage or to the reuse system. Monitoring shall be on a continuous (on-line) basis and shall include an alarm system to indicate failure of high-level disinfection prior to system storage or to the reclaimed water reuse

system. Instruments for continuous on-line monitoring of the turbidity and disinfectant residual shall be routinely calibrated and maintained.

5. The domestic wastewater residuals shall be sampled after final treatment but prior to land application for the parameters listed below every 3 months. A copy of the analyses shall be submitted with the monthly operation report for the following parameters:

Total Nitrogen	% dry weight
Total Phosphorus	% dry weight
Total Potassium	% dry weight
Cadmium	mg/kg dry weight
Copper	mg/kg dry weight
Lead	mg/kg dry weight
Nickel	mg/kg dry weight
Zinc	mg/kg dry weight
pH	standard units
Total Solids	%

6. The permittee shall ensure that neither ponding nor run-off from the spray site occurs as a result of the spray irrigation of the wastewater. Direct discharge from the Golf Courses, sprayfields or the holding ponds to area surface waters is not allowed. Surface discharge shall be considered a violation of this permit and the permittee shall immediately report any such discharge to the SW District Office of the Department of Environmental Protection.

7. The permittee shall provide an approved flow measurement device on the WWTP effluent equipped with a recorder and an integrator or totalizer. The flow measurement device shall be calibrated at least annually, with evidence of calibration kept at the site of flow measurement, and submitted to the Department upon request.

8. The permittee shall properly operate and maintain the facility and systems of treatment and control (and related appurtenances) that are installed and used by the permittee to achieve compliance with the conditions of this permit, are required by Department rules. This provision includes the operation of backup or auxiliary facilities or similar systems when necessary to achieve compliance with the conditions of the permit and when required by Department rules.

9. If, for any reason, the permittee does not comply with or will be unable to comply with any condition or limitation specified in this permit, the permittee shall immediately provide the Department with a description of and cause of noncompliance and the period of noncompliance, including dates and times; or,

if not corrected, the anticipated time the noncompliance is expected to continue, and steps being taken to reduce, eliminate, and prevent recurrence of the noncompliance.

10. The permittee shall hold at the facility or other location designated by this permit records of all monitoring information (including all calibration and maintenance records and all original strip chart recordings for continuous monitoring instrumentation) required by the permit, copies of all reports required by this permit, and records of all data used to complete the application for this permit. These materials shall be retained at least three years from the date of the sample, measurement, report, or application unless otherwise specified by Department rule.

11. Records of monitoring information shall be maintained including the following:
    - the date, exact place, and time of sampling or measurements;
    - the person responsible for performing the sampling or measurements;
    - the dates analyses were performed;
    - the person responsible for performing the analyses;
    - the analytical techniques or methods used;
    - the results of such analyses.

1.6 SLUDGE LAND APPLICATION PERMIT

The MacDill WWTP is permitted to land apply digested sludge at Hudson Farms in Charlotte and DeSoto Counties. The permit contains requirements for monitoring of sludge, as discussed in Section 1.5.

Currently, sludge from the MacDill WWTP is processed through two uncovered, unheated digestion tanks. The EPA Part 503 Biosolids Rule and the pending Florida Administrative Code (FAC) Chapter 62-640 Residuals Management Rules require that biosolids meet pathogen and vector attraction reduction requirements prior to land application. The facility's permit classifies the MacDill WWTP biosolids as stabilization Class B residuals. Under the proposed Florida rules, Class B residuals must undergo treatment in a Process to Significantly Reduce Pathogens (PSRP). The anaerobic digesters at MacDill AFB WWTP must meet the requirements for a PSRP due to the Mean Cell Residence Time (MCRT) and temperature requirements of 60 days at 20°C or 15 days at 35° - 55°. Under 503, Class B pathogen reduction requirements are identical for anaerobic digestion. In addition, under 503 Rules a vector attraction reduction alternative must also be met.

An important aspect of the Part 503 Biosolids Rule that must be kept in mind is that the Rule is self-implementing. Essentially, this means that regardless of whether a permit has been issued by the EPA, the state or local authority, the requirements of the rule are still in force.

1.7 PERSONNEL REQUIREMENTS

1.7.1 Certification Requirements

The MacDill AFB WWTP is an activated sludge wastewater treatment plant within the State of Florida and as such, must comply with the rules of the Florida Department of Environmental Protection (FDEP). FDEP, in the operations permit issued to MacDill AFB, requires that the WWTP be staffed by a Class C certified operator 16 hours per day, 7 days per week. The plant is also required to have Class B domestic plant operator in charge. The WWTP meets these requirements. The WWTP Superintendent, possesses a Class B certificate. The requirements for obtaining a Class B certificate are as follows:

- Hold a valid "C" certificate in wastewater treatment
- Successfully complete a "B" level examination
- Have a minimum of two years of actual operating experience as an operator of a wastewater treatment plant

Certificates issued by the State must be renewed bi-annually. Currently there are no training requirements in place for recertification.

1.7.2 Manpower Requirements

The MacDill AFB WWTP is staffed by one WWTP Superintendent four WWTP Operators and three Industrial Mechanics. These eight positions are all full-time civilian positions. There is also one military operator assigned to the group. The overall management of the WWTP is directed by the Superintendent of the WWTP. In his absence, the Chief Industrial Mechanic serves as acting superintendent of the WWTP. The staff described is responsible for staffing the plant 16 hours per day, seven days per week. Most of the laboratory analyses required for permit compliance are contracted out. A small amount of in-house lab work is performed by the plant staff for process control purposes. In addition to the wastewater treatment plant and laboratory, the O&M personnel are responsible for 50 lift stations, 2 water booster stations, 2 ground water storage tanks, 2 elevated water storage tanks, grounds and building maintenance, 2 wastewater package plants and disposal of trash from arriving overseas aircraft. For six months of the year the WWTP staff is responsible for the operation and maintenance of the two base swimming pools. The military position allocated to the plant is available only approximately 10 percent of the time to WWTP O&M activities.

CHAPTER 2
DESCRIPTION OF FACILITY

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2.1 INTRODUCTION

The purpose of this chapter is to provide a thorough description of the processes and equipment at the MacDill AFB wastewater treatment plant. This description is designed to present a general understanding of the systems involved in the plant, how they function, and how they are interrelated. Some numbers regarding the equipment sizes and capacities are included when necessary.

2.1.1 General

The MacDill AFB wastewater treatment plant consists of a biological treatment system employing the activated sludge process and tertiary filtration. The plant utilizes preliminary, secondary and tertiary treatment processes and anaerobic sludge digestion. A flow schematic of the MacDill AFB WWTP was provided in Figure 1.1.

2.2 COLLECTION SYSTEM AND LIFT STATIONS

2.2.1 Collection System

The wastewater collection system consists of gravity flow piping, lift stations, and force mains. The majority of the collection system is gravity flow. The collection system for the MacDill AFB wastewater treatment plant receives primarily domestic wastewater from the eastern half of the base, the industrial facilities along the flight line and a small portion of the western half of the base. The remainder of the western half of the base, which has fewer facilities and much lower population densities, is served by numerous septic systems and two package wastewater treatment plants. There are also a number of abandoned septic systems and three unserviceable treatment units (package plant, oxidation pond, and sand filter/dosing tank) on the base. The major sources of wastewater flow to the WWTP are:

- Base housing area
- Hospital
- Maintenance shops
- Flightline area
- Administrative office buildings

Non-domestic wastewater from maintenance shops and hangars are normally pretreated to remove floating oils prior to their discharge to the sanitary sewer. Non-domestic wastewater is further discussed in Chapter 10.

The existing collection system was installed with clay, cast iron, and asbestos/cement pipe. The original clay pipe collection system was installed about 45 years ago and was a combined sanitary and storm sewer system. Since that time, the wastewater collection system has been expanded using asbestos/cement and cast iron pipe. During this expansion period, the storm water system was separated from the sanitary system. All known instances of cross-connection for the two collection systems have now been eliminated, although an analysis of rainfall data and flow data indicate a pattern related to infiltration and inflow.

As the wastewater collection system has aged, the older pipe has begun to fail. Pipe age ranges from approximately 45 years to one year. The base has maintained a program to upgrade the older pipe and prevent pipe failure. Due to the extent of upgrading, no given area of the base can be characterized by pipe type or age. The piping upgrades have consisted of replacement of aged pipe with new pipe and the lining of old or weak sections with polyvinyl material. A program to reseal all of the lateral connections to the sewage collection mains has been ongoing for the last eight to nine years. The majority of the infiltration problems have been occurring at the connection points to the mains.

2.2.2 Lift Stations

There are currently 50 wastewater lift stations located throughout the Base. The majority of these lift stations, and all of the seven major lift stations, are located on the eastern half of the Base. Most of these stations function to either collect and pump wastewater from buildings to the gravity system or to "lift" the wastewater back to the gravity system when gravity mains reach the maximum invert. The seven major lift stations pump through a system of force mains that eventually discharge through an 18-inch diameter force main at the WWTP headworks. The seven major lift stations are No. 21, No. 22, No. 62, No. 633, No. 705, No. 706 and No. 718. A separate four-inch diameter force main from the lift stations at the mobile home park also discharges at the WWTP headworks. The age of the lift stations and force mains ranges from approximately 20 years to less than one year.

Lift stations on the Base range from small, fractional horsepower one-pump (simplex) stations to large triplex submersible pump lift stations with a dedicated emergency power diesel generator and telemetry connections to the WWTP. The Base lift stations are listed in Table 2.1.

Table 2.1 - Lift Stations

NAME/NUMBER	PUMP LAYOUT	LOCATION/COMMENTS
DRMO pkg plant	Simplex	DRMO; 2.8 hp
DRMO pkg plant	Simplex	DRMO; 2.8 hp
DRMO pkg plant	Simplex	DRMO; 2.8 hp
Entomology	Duplex	Entomology; to drainfield
Hanger 4	Simplex	Hanger 4
Hospital Supply	Duplex	Hospital supply
Hush House	Simplex	Hush house
Hush House	Simplex	Hush house
Hush House	Simplex	Hush house
P8	Simplex	Wash rack
Pavillion	Duplex	Pavillion; fam camp area
Pistol Range	Duplex	Pistol range
Zone 1	Simplex	NW corner of Base (Zone 1)
21	Triplex	Across from BOQ; generator
22	Duplex	Redcom parking lot; bar screen
39	Duplex	Flight line, near Bldg 48
49	Simplex	Flight line, Bldg 49
62	Duplex	Front of hospital

Table 2.1 - Lift Stations (Cont'd.)

NAME/NUMBER	PUMP LAYOUT	LOCATION/COMMENTS
Zone 69	Duplex	Flight line (old tower)
70	Simplex	E of Bldg 69 on corner of flight line
73	Duplex	Marina trailer park
78	Duplex	Adjacent to JCSE (ammo area)
86	Duplex	Inside radar site
185	Duplex	Flight line
194	Duplex	Flight line
354	Simplex	Next to housing referral
518	Simplex	Flight line wash rack; o/w separator
552	Simplex	Flight line; o/w separator
610	Duplex	Front of Bldg. 717
633	Duplex	Enlisted housing area; generator; bar screen
696	Duplex	Next to hospital supply
698	Simplex	Fam camp area
699	Duplex	Golf course club house
705	Duplex	Base mobile home park, west
706	Duplex	Base mobile home park, east
717	Duplex	Bldg 717 near WWTP
718	Duplex	Road to retention pond
822	Duplex	Ammo storage area
844	Duplex	Past sanitary landfill
869	Duplex	Officers housing area (20 homes)
932	Duplex	Burger King
970	Duplex	Champus office
1063	Duplex	Flight line behind commissary; o/w separator
1065	Duplex	N of apron taxiway; o/w separator
1144	Simplex	N of apron taxiway; o/w separator
1148	Simplex	Mole hole area
1161	Simplex	North of control tower; to drainfield

Table 2.1 - Lift Stations (Cont'd.)

NAME/NUMBER	PUMP LAYOUT	LOCATION/COMMENTS
1873	Duplex	Fam camp area
1887	Duplex	
2017	Duplex	Marina

2.3 PRELIMINARY TREATMENT

The preliminary treatment processes employed at the MacDill AFB WWTP are influent screening, flow metering and sampling, grit removal, equalization, and pumping.

2.3.1 Influent Screening

Raw wastewater enters the treatment plant headworks through an 18-inch diameter force main from satellite lift stations and a 4-inch diameter force main from the lift stations at the mobile home park. Influent flows through a mechanical fine screen located in one influent channel or though a parallel channel which is normally closed by shear gates. This unused channel was previously a grit channel, with a grit channel dewatering pump located on the dividing wall. A single 2-horsepower hydraulic system powers the screen which has a rated capacity of 4.0 mgd. The screen is designed to be self-cleaning and remove materials larger than 1/4-inch diameter from the influent flow. Screenings are washed into a hydraulic powered trough and screw conveyor assembly which conveys the solids into a 30-gallon garbage can placed under the screw conveyor discharge. The screw conveyor has a rated capacity of 14.1 cubic feet per hour. The screen automatically operates based on a timer or on high channel level, or can be run manually using a local HAND-OFF-AUTO switch. High channel level is sensed by an upstream ultrasonic level controller.

2.3.2 Influent Flow Metering and Sampling

Downstream of the influent screen, flow enters the 12-inch wide Parshall flume, which has a measurement range of 0.078 mgd to 10.4 mgd. The differential water level is transmitted by a stilling well/float system to the adjacent flow meter. The flow signal is transmitted to a 24-hour chart recorder and totalizer in the WWTP laboratory.

A non-refrigerated, composite, portable influent sampler obtains samples downstream of the Parshall flume. Ice is used to cool the sample container when the required bi-weekly influent sample is obtained. The sampler in normally run every other Monday, with samples obtained on a timed basis.

After the influent sampling point, influent flows through a manual bar screen to the grit removal system.

2.3.3 Grit Removal

The grit system and flow equalization basin can be bypassed if required, by operating the appropriate knife gate valves. Influent flow normally enters the 4.0 mgd capacity grit removal system through an 18-inch pipe. In an 8-foot diameter circular steel tank, a 1-horsepower motorized impeller is designed to impart both an elevating force to keep lighter solids in suspension and a clockwise flow rotation. The heavier grit settles to a center well and, based on a timer setting, is pumped to an adjacent vortex grit concentrator and 1-horsepower inclined screw grit classifier. Water that is removed is

returned to the influent flow stream upstream of the grit removal system, while dewatered grit is conveyed by the screw classifier into a 30-gallon garbage can.

2.3.4 Equalization Basin

Screened and degritted influent wastewater flows through an 18-inch pipe to the aerated equalization basin, which also receives both tertiary filter backwash water and final clarifier skimmings through an 8-inch pipe. The equalization basin dampens the fluctuating hydraulic and organic loadings on downstream processes at the plant. The equalization basin is 61 feet wide by 61 feet long and 12 feet deep with an approximate usable capacity of 250,500 gallons at a maximum sidewater depth of 9 feet. A minimum water depth of 3.75 feet is maintained in the basin to keep the diffusers and main pump station suction line submerged, leaving a capacity of 146,100 gallons available for equalization. The equalization basin is equipped with two 7.5-horsepower, 300 scfm rotary positive displacement blowers for aeration and mixing through a system of air headers, laterals and coarse bubble diffusers. The bottom of the air laterals are located 2 feet above the bottom of the basin. The blowers are manually controlled through locally mounted ON/OFF controls. The equalization basin is connected to the main pump station by an 18-inch pipe. Float switches in the main pump station wet well control the level in the equalization basin.

2.3.5 Main Pump Station

The main pump station receives both influent from the equalization basin and return activated sludge (RAS) from the three final clarifiers. Influent enters the station wet well through an 18-inch pipe, while RAS flows from three 8-inch telescoping valves through a 6-inch Parshall flume, where it is metered before mixing with the influent. Differential water level is sensed and transmitted by a stilling well/float system to the adjacent flow meter. The RAS flow is metered and recorded on a circular chart recorder located in the plant laboratory.

The main pump station consists of three centrifugal pumps located in a dry well, one dry well sump pump, associated pump controls, three 7.5-horsepower two-speed motors and seven float switches located in the adjacent wet well. The motors are located on top of the structure, connected to the pumps by vertical shafts. The pumps are rated for 1,100 gpm at high speed and 400 gpm at low speed, with operation of the pumps controlled by the seven floats in the following sequence: off, #1 low, #2 low, #1 high, #2 high, #3 low and #3 high. The lead/lag/lag lag pump can be selected or the pumps operated manually through the local control panels.

2.4 AERATION BASINS

The mixture of raw influent and RAS flows from the main pump station to the two aeration basins through a 14-inch pipe that tees into two 12-inch pipes, which each then discharge near the bottom of each basin. The basins provide biological treatment of the organic wastes. Each aeration basin is 46 feet in diameter with a normal sidewater depth of 12 feet, for a total capacity of approximately 300,000 gallons. The basins have recently been equipped with an aeration system consisting of two 30-horsepower rotary positive displacement blowers rated at 800 scfm each, a 6-inch main air header, 2 1/2-inch air laterals and fine bubble air diffusers. Normally only one blower is operated. Two butterfly valves in the air header can be closed to isolate either basin. Air flow is controlled by a 2-inch bleed-off valve and vertical riser on the main air header.

Effluent overflows a circular weir around the inside of each basin, collects in a launder and flows by gravity through a 14-inch pipe from each basin. The two 14-inch pipes combine into an 18-inch pipe which leads to the final clarifiers.

The current loading rates based on average data from January 1994 - February 1995 to the system are as follows:

Parameter	Current Loading	Recommended Design Criteria
Volumetric Organic Loading	13.3 lbs BOD/1000 ft^3	20-40 lbs BOD/1000 ft^3
Hydraulic Retention Time	12.7 hours	4-8 hours
Food to Microorganism (F/M) Ratio	0.13 lbs BOD/lb MLVSS	0.2-0.4 lb BOD/lb MLVSS

The volumetric organic loading rate is below the lower end of the recommended range for conventional activated sludge systems (i.e., 20 to 40 lb BOD/1000 ft^3). Similarly, the F/M ratio is below the lower end of the recommended range for conventional activated sludge plants (i.e., 0.2-0.4 lb BOD/lb MLVSS). The hydraulic retention time exceeds the recommended range for conventional plants (4-8 hours). None of these loading factors are in a range where problems in treatment efficiency or plant performance would be expected, however, these numbers are based on average data. There were periods during 1994 when the MLSS was less than 1,000 mg/L, which is inadequate to treat even the dilute influent normally entering this facility.

Control of Dissolved Oxygen (DO) in the basins is limited to adjusting the 2-inch bleed off valve on the air header line. The basin DO's should never be allowed to drop below 2.0 mg/L. The recommended minimum DO requirement of 2.0 mg/L applies to all segments and depths of the basins.

2.5 FINAL CLARIFIERS

Effluent from the aeration basins flows to the three rectangular final clarifiers, where the biological solids are settled and either returned to the main pump station or wasted to the anaerobic digesters. Each clarifier is 16 feet wide and 45 feet long with a sidewater depth of 10 feet. The sidewater depth is 2 feet less than the recommended minimum design depth and can have a profound effect on the performance of the clarifiers if other operating and design conditions are less than optimum.

The clarifiers use fiberglass flights and plastic chain driven by a 1.0-horsepower motor on the north and center drives and a 0.5-horsepower motor on the south drive. All units operate continuously.

The flights collect solids into the two sumps per clarifier at the east end and collect floatable skimmings at the west end of the clarifier. Skimmings are removed by manually rotating a slotted pipe skimmer, where they flow by gravity to the skimming pump station located south of the clarifiers. Two 3-horsepower 100 gpm submersible pumps, controlled by floats, return the skimmings to the equalization basin.

The return sludge is controlled by the three 8-inch telescoping valves, one per clarifier, at the main pump station. The underflow rate for each clarifier is increased or decreased by manually lowering or raising the telescopic valves, respectively.

Sludge is normally wasted daily to the waste sludge pit by manually opening a valve (one per sump) using a wrench on the floor-stand operator. The two waste activated sludge (WAS) pumps are 6-inch double disc pumps driven by 20-horsepower motors, and are manually operated through local START/STOP controls. Each pump is belt driven through a reducing sheave, operates at 751 rpm, and has a capacity of 410 gpm at 25 feet of discharge head. The operator can determine the waste sludge flow rate and total sludge wasted by the WAS transit-time ultrasonic flowmeter located on the discharge line of the waste sludge pumps. The WAS flow is recorded and totalized on a chart recorder in the plant laboratory.

Return sludge rates are currently in the range of 25-30 percent of influent flow, which is much less than design recommendations of 50-100 percent.

Current available surface area for the three units combined is 2,160 ft^2. Current available volume is 161,500 gallons. Operating parameters for the final clarifiers under average flow conditions of 0.60 mgd are as follows:

Parameter	Current Loading	Recommended Design Criteria
Surface Loading Rate	262 gpd/ft^2	400-800 gpd/ft^2 (Average) 1000-1200 gpd/ft^2 (Peak Hour)
Solids Loading Rate	3.6 lb TSS/ft^2-d	20-30 lb TSS/ft^2-d (Average) 50 lb TSS/ft^2-d (Peak)
Hydraulic Retention Time	6.9 hours	N/A

The surface loading rate and the solids loading rate are below the recommended design values.

Clarified effluent overflows weirs at the west end of the clarifiers and flows by gravity through a 24-inch pipe before reducing to a 16-inch pipe leading to the distribution well in the center of the tertiary filters.

2.6 TERTIARY FILTERS

Final clarifier effluent flows by gravity to the tertiary filters. Flow enters the filters through a 16-inch pipe into the center feedwell/splitter box, through 10-inch pipes to each of six filter cells, and across the filter surface. Each filter is a multi-media unit, 10.5 feet in diameter, with a total filter bed depth of 4.08 feet. The top layer of filter media, 18 inches of crushed anthracite, is on top of 18 inches of graded sand followed by 13 inches of graded gravel. Filter effluent is collected in an underdrain system of perforated pipe and flows out of the filters through a 10-inch line to the backwash tank. Flows in excess of that required for backwash are discharged into an 18-inch PVC pipe to the chlorine contact tank. Entering each filter bottom is a 3-inch air scour line and 8-inch backwash line. During filter backwashing, this 8 inch line is fed from one of two 720 gpm, 20-horsepower horizontal centrifugal backwash pumps. Backwash waste exits the filters via the wash troughs and flows to the backwash holding tank. From the backwash holding tank, it is pumped to the equalization basin by one of two 720 gpm, 20-horsepower horizontal centrifugal backwash holding pumps. The air scour system is equipped with one 15-horsepower, 346 scfm positive displacement blower. A small air compressor system supplies air to the pneumatic valves.

Based on an average daily flow of 0.566 mgd and 87 square feet per cell, the loading rate for the filters is 0.75 gpm/ft^2. The manufacturers recommended average loading is 2.0 gpm/ft2, with a maximum loading of 5.0 gpm/ft.

Prior to overflowing a discharge weir at the tertiary filters, filtered effluent flow, pH and turbidity are measured. An ultrasonic flow meter transmits a flow signal to the automatic chlorinator and to the chart recorder and totalizer in the plant laboratory. A pH probe is located in the effluent flow stream and a continuous reading is obtained and displayed in the laboratory. A continuous filtered effluent turbidity sample is obtained by a sample pump, and pumped to the turbidimeter which transmit a turbidity reading to be displayed and recorded in the plant laboratory. The turbidity sample pump discharges into the aeration basin drainage sump, which is equipped with a signal sump pump discharging into the aeration basin.

The tertiary filters discharge to the chlorine contact tank splitter box through an 18-inch gravity line. Chlorine is added to the effluent flow by a chlorine solution injector/diffuser, located below ground in the 18-inch line.

2.7 CHLORINE CONTACT TANK

The chlorine contact tank was designed to provide sufficient chlorine contact time to meet the high level disinfection requirements of 15 minutes contact time at peak hourly flow for reclaimed water.

Flow enters the chlorine contact tank through the splitter box at the east end, where two slide gates with handwheel operators control the flow into two serpentine chambers. Each chamber consists of three channels 5 feet wide and 47 feet long, and with a normal sidewater depth of 5.5 feet, have an approximate capacity of 29,600 gallons. Normally only one chamber is in use at a time. A slide gate controls flow at the west end of each chamber, which overflows into a common effluent pump station wet well. A 0.33-horsepower pump at the pump station wet well supplies a chlorinated effluent sample to the locally-mounted chlorine analyzer.

The chlorination building contains a chlorine cylinder scale which holds two 150-pound cylinders (one on-line, one on standby), cylinder-mounted vacuum regulators, an automatic switchover unit, a 100 pound per day capacity wall-mounted automatic chlorinator, a chlorine gas detector with battery backup power, a turbidimeter, and a turbidity sample pump. The automatic chlorinator varies the chlorine gas feed rate based upon a flow signal received from the ultrasonic flow meter at the tertiary filters.

2.8 EFFLUENT PUMP STATION

An effluent pump station is located at the west end of the chlorine contact tank, and consists of two 1,600 gpm, 10-horsepower vertical turbine effluent pumps, two 1,000 gpm, 100-horsepower vertical turbine effluent sprayfield pumps and two 800 gpm, 18-horsepower submersible effluent recycle pumps. Normally, effluent which meets reclaimed water standards of total suspended solids, pH and chlorine residual is pumped to the holding pond by the effluent pumps through a 12-inch pipe. If reclaimed water does not meet any of the above quality criteria, the effluent pumps are locked out and the effluent sprayfield pumps pump to the restricted access sprayfields through a 12-inch pipe. In the event that the flow is greater than the capacity of the sprayfield pumps, the effluent recycle pumps return the flow back to the equalization basin through an 8-inch pipe. All three effluent lines are equipped with transit-time ultrasonic flowmeters, which transmit flow signals to a three pen chart recorder and totalizer in the plant laboratory.

The operation of the pumps is based on floats in the wet well and the quality of the effluent, as measured by the turbidimeter, chlorine residual analyzer and pH probe. Only one of the sprayfield pumps is allowed to operate at a time.

2.9 EFFLUENT HOLDING POND

The effluent holding pond has a normal operating depth of 4.5 feet and a capacity of approximately 4 million gallons. At the northwest corner of the pond, a 24-inch pipe connects the pond to an old out-of-service chlorine contact tank. Two vertical turbine golf course irrigation pumps, located in a building at the end of the tank, provide water to the north and south golf courses. One of the vertical turbine pumps is rated at 200 gpm at 300 feet of head; the second pump is rated at 800 gpm at 300 feet of head. The vertical turbine pumps are operated and maintained by golf course personnel. Two 40-horsepower, 400 gpm horizontal centrifugal pumps are located in a separate dry well adjacent to the old chlorine contact tank. These pumps are float operated based on high pond level and pump to the effluent sprayfields.

2.10 EFFLUENT SPRAYFIELDS

Four effluent sprayfields, with a total area of 82.4 acres, are included in the current FDEP permit. Of these four sprayfields, only one and one-half are currently usable. The largest sprayfield, No. 1, is located in a wooded area, and is out of service due to a broken transmission line and nonfunctional valves and spray heads. Sprayfield No. 2 has been abandoned due to the construction of the Florida Air National Guard building and the current construction of a satellite communication facility on the previous site of the sprayfield. Sprayfield No. 3 has a broken transmission line on the north half, but the south half can still be used. Sprayfield No. 4, an area contained within a 30.5 acre plot, is used on a consistent basis.

2.11 ANAEROBIC DIGESTERS

Two 40-foot diameter uncovered digesters, with a maximum sidewater depth of 20 feet, are used to partially digest and hold waste sludge prior to being trucked to land disposal by a contractor. Each digester has a capacity of 192,600 gallons, for a total capacity of 385,200 gallons. The primary digester contains a 4-horsepower, 5,400 rpm submersible propeller mixer, which can be raised and lowered by a hand winch from atop the digester, and controlled from a local control panel with START/STOP pushbuttons. The secondary digester is unmixed, and neither digester is heated.

Three sludge pumps are located on the lower level in the building between the two digesters. Two 6-inch double disc, 20-horsepower pumps operate at 506 rpm through a belt driven reducing sheave. These pumps are each rated at 410 gpm at 25 feet of discharge head and are used to load sludge hauling trucks. A 5-horsepower, 250 gpm vertically mounted centrifugal pump is used for sludge transfer between digesters. An ultrasonic meter is installed on the sludge transfer line between the two digesters, and the flow signal is transmitted to a chart recorder and totalizer in the plant laboratory. The existing sludge drying beds are not used.

Average daily waste activated sludge flow to the digesters is approximately 5,000 gallons, with an average waste sludge concentration approximately 3,200 mg/L. Therefore, the current loading factor is approximately 0.005 lb TSS/ft^3-d. This loading level is below the design range for anaerobic digesters (i.e., 0.04-0.1 lb VSS/ft^3-d).

2.12 SLUDGE LAND APPLICATION SYSTEM

The MacDill WWTP is permitted to land apply digested sludge at Hudson Farms in Charlotte and DeSoto Counties. A contractor provides sludge hauling services on an as-needed basis. The volume of sludge hauled is determined from the capacity of the truck and the number of loads.

CHAPTER 3
THEORY OF OPERATION OF UNIT PROCESSES

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THEORY OF OPERATION OF UNIT PROCESSES

3.1 PRELIMINARY TREATMENT

3.1.1 Introduction

Incoming wastewater to a treatment plant contains a very diverse blend of constituents. Coarse materials such as string, rags, paper, cans, and wood can enter a plant through the sewer system. Wastewater also contains a relatively large amount of inorganic solids such as sand, gravel, and cinders which are collectively called grit. Besides being unaffected by biological treatment, materials such as the above can damage pumps and other equipment as well as plug pipelines. Removal of these materials helps to prevent disruption of downstream processes and to protect equipment. The MacDill AFB WWTP contains several preliminary treatment processes designed to remove these materials.

3.1.2 Screening

Screening was one of the first methods used to remove large solids from wastewater. The main purpose of many of the first wastewater plants was to only remove the visible, large solids. Coarse screens are normally employed as the first treatment unit for the primary purpose of protecting plant equipment from physical damage or reduced operating efficiency. Manual bar screens are located in Lift Stations 22 and 633 and at the MacDill AFB WWTP.

Bar screens fall into two categories, manually cleaned and mechanically cleaned. Manually cleaned bar screens are labor intensive and are therefore generally only found in small plants. Screenings are removed by the operator using a rake or similar device. Mechanically cleaned bar screens are the most common type of screening device employed today. The use of mechanically cleaned bar screens tend to reduce labor costs, provide better flow conditions and cause less nuisance. The mechanical cleaning devices consist of rakes that periodically sweep the entire screen, removing the solids for

disposal. Most mechanical bar screens use chains or cables to move the rake teeth through the screen openings. After the rake has cleaned the screen it drops its accumulation into a holding container for ultimate disposal, generally by burying.

The size of screen openings is usually determined by the operation that follows the screen. Bar sizes in screens are usually 1/4 inch to 5/8 inch in width by 1 inch to 3 inches in depth. Spacing of the bars ranges from 0.75 inch to 3 inches. Velocity through the screens is usually in the range of 1.5 to 3 feet per second. Large screens are sometimes set vertically. Generally screens are set at an angle of 15 to 30 degrees to the vertical.

Screens must be cleaned at periodic intervals to prevent excessive accumulations on the bars and to prevent backup of the wastewater upstream of the screens. The screening cycle is typically set by a repeat timer, with an override by a high float switch upstream of the screen. Occasionally screens are run continuously if the influent is high in screenable solids.

3.1.3 Grit Removal

The function of grit chambers is to remove large inorganic solids such as sand, gravel, or cinders. They are designed to remove solid materials that have subsiding velocities or specific gravities substantially greater than those of the organic solids in wastewater. Most grit chambers are constructed to capture particles with a specific gravity greater than 2.65 and a diameter larger than 0.02 centimeters.

The objective of grit removal is to remove the inorganics from the wastewater flow with a minimum of organic materials also being removed. If flow rate through a grit chamber is too high, little inorganic material will settle out. If flow rate is too low, a large amount of organic matter will settle out with the grit. Excessive organic matter in the grit leads to more frequent cleaning of the grit chambers and can lead to odor problems while the grit is stored awaiting disposal. The grit chamber at the MacDill AFB is at the headworks of the WWTP.

3.1.4 Grit Collection

Accumulation of settled grit at the bottom of grit chambers must be removed regularly. If cleaning is ignored, the efficiency of the unit will decline and cause unwanted material to pass into the plant. At the MacDill WWTP, grit settles in a circular, velocity controlled grit chamber, is moved by a rotating mechanism to a center sump, and is then removed by a grit pump to a grit dewatering system and screw conveyor.

3.1.5 Grit Dewatering

After grit is removed from grit chambers it generally goes through a process of further dewatering. Common dewatering devices are hydroclones (or cyclones), classifiers and separator screens. Water and grit are separated in the hydroclone through the use of centrifugal force. Heavier grit is settled toward the wall and discharged through one end while the liquid portion passes out of the separator through another. The grit concentrator operates on the same principal.

3.1.6 Grit Disposal

The different methods of grit disposal include sanitary landfills, lagoons, and land spreading. In general, it is best to bury and cover the grit, as the residual organic content can still be a nuisance. Since grit has good structural stability, it will not cause problems with future use of the land. The grit may be combined with other waste solids from the treatment plant before disposal. The MacDill AFB WWTP grit is currently deposited in a dumpster and hauled to a disposal site.

3.2 BIOLOGICAL TREATMENT PROCESS

3.2.1 Introduction

Biological treatment is the most important step in processing domestic wastewater. Physical treatment of wastewater by sedimentation only removes about 35 percent of the biochemical oxygen demand (BOD) due to a high percentage of nonsettleable organic solids (colloidal and dissolved) in domestic wastes. Chemical treatment alone is not favored because of high costs. A modern treatment plant uses a variety of physical, chemical, and biological processes to provide the best, most economical treatment.

Biological treatment systems are "living" systems which rely on mixed biological cultures to break down waste organics and remove organic matter from solution. Domestic wastewater supplies the biological food and growth nutrients. A treatment unit provides a controlled environment for the desired biological process.

Wastewater treatment operations contain communities of microorganisms made up of populations of individual species. Within the community, changes can occur in populations present as the system responds to changes in the quantity and character of the material entering in the feed stream or to changes in the physical environment. If the nature of the waste being treated is such that it supports a broad and diverse microbial community, the community will adapt readily to changing environmental conditions, and the system will appear fairly stable from the microscopic point of view. Under some circumstances, the community may be restricted. This leads to an unstable biochemical environment and a process which is difficult to control. Generally, complex integrated communities with a large number of diverse species are considered to be healthy ecosystems.

3.2.2 Microorganisms in Biological Systems

3.2.2.1 Bacteria

Bacteria are the simplest forms of plant life which can use soluble food and are capable of self-reproduction. Bacteria are single-celled, independent organisms with each cell capable of carrying out all necessary functions of life. Bacteria are fundamental microorganisms in the stabilization of organic wastes and therefore of basic importance in biological treatment. Uncontrolled, bacterial decomposition of organic wastes can

produce odors and objectionable conditions. In controlled environments, bacteria can stabilize organic matter and prevent objectionable conditions.

Based on nutrient requirements, bacteria are classified as heterotrophic or autotrophic, although several species may function both heterotrophically and autotrophically.

Heterotrophic bacteria use organic compounds as an energy and carbon source for synthesis. A term commonly used instead of heterotroph is saprophyte, which refers to an organism that lives on dead or decaying organic matter. The heterotrophic bacteria are grouped into three classifications depending on their action towards free oxygen. Aerobes require free dissolved oxygen to live and multiply. Anaerobes oxidize matter in the complete absence of dissolved oxygen. Facultative bacteria are a class of bacteria which use free dissolved oxygen when available but can also respire and multiply in its absence.

Autotrophic bacteria use carbon dioxide as a carbon source and use inorganic compounds for energy. Autotrophs of greatest significance in wastewater treatment are the denitrifying and sulfur bacteria.

Bacteria are also classified according to the temperatures at which they thrive. The largest proportion of saprophytes thrive at 20° to 40°C or 68° to 104°F and are called mesophilic types. Variations from this temperature range limit the activity of mesophilic bacteria, practically eliminating them at high and low temperatures. Other bacteria thrive at higher temperatures, in the range of 55° to 66°C or 130° to 140°F. These are known as thermophilic types. Very few types find their optimum temperatures at low temperatures (0° to 5°C or 32° to 40°F). These are known as psychrophylic bacteria. Mesophilic bacteria are important in all biological treatment systems. Thermophilic bacteria are important in some sludge digestion systems.

Bacteria have the ability to reproduce rapidly when in intimate contact with their nutrient material (i.e., wastes) and feed readily by taking in food directly through their cell walls. Bacteria occur in three basic shapes: rods (bacilli), spheres (cocci), and spirals. While all these forms are found in wastewater, quite often they are found

individually enmeshed or associated in masses, slimes, or flocs. They are capable of growth in suspended or attached masses.

3.2.2.2 Fungi

Fungi are heterotrophic microorganisms which are predominantly filamentous (stringy) in nature and quite different in shape from the bacteria. Fungi are multicellular as opposed to the single-celled bacteria. Generally, fungi are somewhat larger than the bacteria and do not have a primary role in wastewater treatment. At times, certain fungi can cause serious interferences or nuisance problems in wastewater treatment, especially in settling. This generally occurs in low pH or low nitrogen environments.

3.2.2.3 Algae

Algae are microscopic autotrophic-photosynthetic plants. The process of photosynthesis is illustrated by the equation:

$$CO_2 + 2H_2O \underset{\text{dark reaction}}{\overset{\text{sunlight}}{\rightleftharpoons}} \text{New Cell Tissue} + O_2 + H_2O$$

Energy for photosynthesis is derived from sunlight. Photosynthetic pigments biochemically convert the energy in the sun's rays to useful energy for plant synthesis. The most common pigment is chlorophyll, which is green in color. Other pigments or combinations of pigments result in algae of a variety of colors, such as blue-green, yellowish green, brown, and red. In the prolonged absence of sunlight, the algae perform a dark reaction--for practical purposes the reverse of photosynthesis. In the dark reaction, the algae degrade stored food and their own protoplasm for energy to perform essential biochemical reactions for survival. The rate of this endogenous reaction is significantly slower than photosynthetic reaction.

There are a variety of algae forms that may be found. Raw wastewaters, unless exposed to sunlight, do not usually contain algae, while trickling filters and oxidation ponds have large numbers of algae in areas exposed to sunlight. Algae frequently play an important role in providing oxygen to stabilization ponds through photosynthesis. Because algae grow rapidly as a result of excess amounts of nutrient nitrogen and phosphorous (especially the latter), their excessive growth can be a source of nuisance

problems in streams, lakes, ponds or other bodies of water. The most serious algae problems in receiving waters are associated with the growth of blue-green algae. Trickling filters, final settling tanks, discharge channels, and receiving streams will frequently have filamentous, attached green algae or brown diatoms at different times of the year.

3.2.2.4 Protozoa and Higher Animals

Protozoa are single-celled animals that reproduce by binary fission. The protozoa of significance in biological treatment systems are strict aerobes found in activated sludge systems, trickling filters plants, and oxidation ponds. These microscopic animals have complex digestive systems and use solid organic matter as an energy and carbon source. Protozoa are a vital link in the aquatic food chain since they ingest bacteria and algae and are scavengers and predators in biological treatment processes.

A number of types of protozoa are common to biological processes such as activated sludge. Protozoa with cilia may be categorized as free-swimming and stalked. Free-swimming forms move rapidly in the water ingesting organic matter at a very high rate. The stalked forms attach by a stalk to particles of matter and use cilia to propel their head about and bring in food. Another group of protozoa move by flagella. Long hair-like strands (flagella) move with a whip-like action providing mobility. Amoeba move and ingest food through the action of a mobile protoplasm.

Rotifers are the simplest multicelled animals. They are strict aerobes and metabolize solid food. A typical rotifer uses the cilia around its head for catching food. The name rotifer is derived from the apparent rotating motion of the cilia on its head. Rotifers are indicators of low pollutional waters and are regularly found in streams and lakes.

3.2.3 Bacterial Utilization of Food

As stated earlier, bacteria in biological wastewater systems utilize the incoming waste for food. Bacteria can only use organic wastes which are in a soluble, or dissolved, state. Soluble organics are ingested directly through the cell wall and membrane by the bacteria for utilization. This process is known as absorption, or the taking up of one substance into the body of another.

For insoluble organics or particles too large to be directly absorbed, the process is more complicated. First, the waste particle is adsorbed by the bacteria. This is a process of adherence where the waste particle becomes attached to the cell wall of the bacteria. The bacteria will then begin to secrete enzymes which act to break down the specific organic. As the organic is broken down, it is then taken into the cell, or absorbed.

The utilization of organic waste as food by bacteria is an accumulative process. Initially, when a complex organic is introduced into a biological system, one type of bacteria attacks one part of the organic material and other bacteria attack the remaining parts. The bacteria digest that portion of the organics they have absorbed through their cell walls and produce certain waste products. These waste products are then used as a food source by other microorganisms which, in turn, produce waste products that are subsequently used as food by yet other microorganisms. This accumulative process continues until the original complex organic is completely broken down and assimilated by the biological population.

3.2.4 Factors Affecting Growth

Several factors affect the growth of microorganisms. These include the following:

1. pH. An environmental factor which influences the growth rate and limits the growth in any biological system is the hydrogen ion concentration, i.e., the acidity or alkalinity of the liquid environment of the process. This is most conveniently expressed as the pH of the system.

   Each species of microorganism is limited by a range of pH values within which growth is possible. The optimum pH value for any species is that at which the growth rate is most rapid. Often this pH range is surprisingly broad. Most bacteria and protozoa have pH optima near 7 but thrive in a range of 5 to 8.

   In biological populations found in waste treatment plants there are a series of individual species of microorganisms acting and interacting at the same time. Within this community, species changes can occur as the system responds to changes in the type or quantity of the organic material entering the influent stream. The activities of the species as they feed upon the organic matter and

grow result in the formation of acidic or alkaline products. As these products are released from the cell, an increase or decrease in the system pH may occur.

Each biological system can accept flows within a pH range without upsetting the system or changing the internal system pH. In some systems this range is narrow, but some systems have been known to accept flows with pH variation of 5 to 11 without noticeable effects. pH changes of long duration above or below the acceptable range a system can tolerate are considered toxic. Wide fluctuations in pH for short periods of time can usually be tolerated by a healthy system.

2. Nutrients. All living cells require a number of basic nutrients for survival. Generally, the two most important for biological systems are nitrogen and phosphorous. These nutrients must exist in certain proportions to maintain a healthy population of microorganisms in the system. Both nitrogen and phosphorous are necessary to maintain cell respiration and reproduction. Nitrogen is needed for generating new cell material, while phosphorus is essential to enzyme production. If the amount of these nutrients added is not sufficient, the formation of unwanted types of microorganisms is likely to occur.

   Generally, a good rule of thumb for nutrient balance in the incoming wastewater to a biological treatment system is that for each 100 parts of raw BOD5, there should be about 5 parts of total nitrogen and 1 part of total phosphorus.

3. Temperature. In order to function at maximum efficiency, bacteria require a favorable temperature. They are very susceptible to changes in temperature in that their rate of growth and reproduction is definitely affected by such variations.

   As stated earlier, the larger portion of these bacteria thrive best at temperatures from 20°C to 40°C or 68°F to 104°F. These are known as "mesophylic" types. Variations from this temperature range limit the activities of mesophylic bacteria, practically eliminating it at extremely low temperatures and at high temperatures. Temperatures, consequently, are of major importance in the operation of a biological process.

The optimum temperature is that at which the growth is most rapid, and for most bacteria it is closer to the maximum than to the minimum temperature. Growth at the minimum temperature is typically quite slow. The rate increases exponentially, with increasing temperature reaching a maximum at the optimum temperature and falling abruptly to zero at a few degrees above the maximum. For most organisms, the growth rate increases twofold for each 10°C rise in temperature between the minimum and optimum.

Time is an important factor in considering the effects of temperature, particularly temperatures above the range of growth. Some effects of elevated temperatures are reversible, and short exposure to an elevated temperature may not be lethal, although longer exposure at that same temperature would be. The higher the temperature, of course, the less time is required for killing and the greater is the probability that irreversible damage will occur.

When an organism is subjected to a temperature change within the biologically active range, the response of the organism at the new temperature depends on the ability to adapt or acclimate to the new environment. In areas with prominent seasons, the temperature changes from winter to summer or summer to winter can cause plant upsets, sometimes of a serious nature.

4. Oxygen Supply. In aerobic biological systems, an adequate oxygen supply is necessary for growth to occur. Oxygen can be introduced to the biological culture through various means depending on the type of systems. Some derive their oxygen supply from the microorganisms themselves, as in the case of algae in ponds. Ventilation, either natural or forced, is required in processes such as activated sludge.

5. Shock. A shock can be defined as any abrupt change in the feed to the system that may result in a process upset. A process shock can be classified as:

    - A qualitative shock - a change in the type of organic substances fed to the organisms;
    - A quantitative shock - a change in the total amount of organic substances fed to the system;
    - A hydraulic shock - a sudden change in flow rates;

- Toxic shock - this includes such things as pH, temperature, conductivity, toxic materials, etc.

  Of major concern in a plant is the degree of shock that can be tolerated at any one time without causing process upsets and permit violations. Important points for personnel to realize in handling shock loads are:

- Biological processes can handle shock loadings up to a certain degree.
- The degree of shock that can be tolerated by a plant depends upon the stability of the plant at that particular time. (Plants in the process of recovering from one type of shock are less likely to be able to withstand another shock if this second shock occurs during this recovery period.)
- Complete effects of some shock loads are not immediately visible.
- Temporary rises in flow rates, organic loads, or chemical or physical changes (referred to as spikes) do not necessarily constitute shock loads. Equalization capabilities of the plant will dampen the effect of these "spikes" and they often will pass through the process with no adverse effects.

3.2.5 Equalization

One of the most frequently encountered problems in wastewater treatment is process upsets related to highly variable contaminant levels or intermittent high flow rates. Such variability in wastewater composition and quantities can result from high rainfall or unauthorized dumping of material into the collection system. These fluctuations can be so severe that process upset and subsequent problems can occur before the system is able to compensate. For this reason, wastewater equalization often is implemented to control the extreme fluctuations in flow and contaminant concentrations. Whenever treatment process upsets do occur, proper operation of equalization should be one of the first operating conditions to be checked.

3.2.5.1 Purpose of Wastewater Equalization

Wastewater equalization can accomplish three basic tasks. The first is hydraulic or flow equalization which dampens flow surges to downstream treatment processes. Flow equalization can only be accomplished by placing some type of variable liquid volume

storage tank in the wastewater flow path upstream of sensitive process equipment. The liquid is stored in the variable volume tank during high flow periods and then is released during low flow periods. Therefore, the flow equalization capability is directly related to the usable variable volume of the tank.

The second equalization task is concentration equalization. Concentration equalization is accomplished by mixing low and high contaminant concentration wastewater, which results in concentrations close to the average and reduces downstream concentration fluctuations. As with flow equalization, some type of storage must be provided which stores highly (or slightly) contaminated flow until such time as the contaminant concentration cycles to the other extreme. Contaminant equalization can be accomplished by placing in the flow path a storage tank and mixer with sufficient volume to mix the low and high concentration wastes.

The third equalization task, an offshoot of the earlier discussed two, is to allow means to control the contaminant mass loading to the downstream treatment process(es) to within limits set by the operator. This is accomplished by increasing or decreasing flows to the process from the equalization basin. The operator would have the option of lowering flow during periods of high concentrations and raising flows during periods of low concentrations and could control the load to the process to desired levels. This system requires some analytical work and requires an equalization tank large enough to allow the operator to vary the tank level. It has the advantage that it can reduce the possibility of shock loading and allows much finer control of the downstream treatment process(es).

3.2.5.2 Flow-Through Equalization

The system of flow-through equalization dampens and greatly reduces flow and concentration variations, but does not eliminate them. Typically, the system operates on a continuous basis and requires a large tank, a mixing system, and an effluent control device such as a weir, orifice, control valve, or variable rate pumping. For flow equalization, the tank must be designed to fluctuate in volume in response to influent flow rates. For contaminant equalization, the tank must be large enough to hold the volume which corresponds to the discharge cycle of high or low concentration wastes. The more cycles the tank can hold, the better the equalization achieved. The effluent

control devices selected will depend on the objective of the equalization. Pumps or flow control valves are used for maximum flow equalization or for controlled equalization of contaminant mass loadings.

The major advantage of a flow-through equalization system is its simplicity of operation and the continuous nature of its discharge. Flow and contaminant concentration changes do occur, but very gradually. This gradual change usually provides downstream processes, such as pH adjustment, with adequate time to respond. The major disadvantage of the system is the large tank size generally required.

3.2.5.3 Operational Considerations

The objective of equalization is to limit fluctuations in wastewater flow and/or contaminant concentrations to levels that will not adversely affect downstream treatment processes.

A. Mixing.

Mixing is an integral part of all equalization techniques. Flow equalization requires mixing to keep suspended material in suspension. Without it, solids will accumulate in the storage tank, thereby reducing the effective volume of the tank. Contaminant equalization requires mixing to blend the low and the high strength wastes together. And in the case of sidestream or batch equalization processes, mixing is required to insure a constant known concentration so that flow may be sent forward to downstream treatment system at a rate which will not cause process upsets. Mixing can also help to maintain aerobic conditions in the equalization vessel, which can be important in reducing odors and gas production should the organics in the wastewater be readily degraded under anaerobic conditions. For all these reasons, proper orientation and maintenance of the equalization mixing systems is critical to optimizing the effectiveness of the process.

B. Routine Process Monitoring.

Equalization monitoring takes two forms. First, with the exception of a continuous flow-through system, the wastewater must be monitored for flow and/or contaminant concentration. Monitoring can be accomplished using either

automated on-line equipment or by periodic measurements by the operator. The former is subject to breakdown and the latter is subject to slow response that may completely miss flow or contaminant surges.

3.2.6 Activated Sludge

One of the most common forms of biological treatment is the activated sludge process. Removal of organic matter from wastewater in the activated sludge process is accomplished by introducing the water to be treated into a tank containing a high concentration of actively growing microorganisms in the presence of dissolved oxygen. The microorganisms use the waste material as a source of food so as to obtain the energy necessary to grow and multiply. In so doing, the microorganisms convert the waste materials into more stable end products such as CO2, water, and more microorganisms. The activated sludge process is illustrated by the basic reaction:

$$\text{Microorganisms} + \text{organic matter} \xrightarrow{O_2} \text{microorganisms} + CO_2 + H_2O$$

As the microorganisms grow and are mixed by the agitators in the aeration basins or reactor, the individual organisms clump together (flocculate) to form an active mass of organisms called "activated sludge." Wastewater flows into the aeration basins, where oxygen is injected and the activated sludge and the wastewater are thoroughly mixed. This mixture is called "mixed liquor."

Generally, the organisms in an activated sludge culture may be divided into four major classes: floc-forming organisms, saprophytes, predators, and nuisance organisms. These are not distinct groups; in fact, any particular organism may fit into more than one category at a time or may change groups as the selective pressures within the community change.

Floc-forming organisms play a very important role in the process, for without them the sludge could not be separated from the treated wastewater. Classification of organisms into the floc-forming group is complicated by the fact that protozoa and fungi can also cause bacteria to flocculate. Nevertheless, this group is primarily composed of bacteria. Flocculation is thought to be caused by natural polyelectrolytes, although their origin is uncertain.

The saprophytes are the organisms responsible for the degradation of organic matter. These are primarily bacteria and no doubt include most of the bacteria considered to be the floc formers. Nonflocculant bacteria are probably also present but are entrapped within the floc particles formed by the first group. The saprophytes can be subdivided into primary and secondary saprophytes, the primary ones being responsible for the degradation of the original substrates. No doubt the larger the number of substrates, the more diverse the community will be because of less competition for the same substrates. The secondary saprophytes feed upon the metabolic products of the primary ones.

The main predators in activated sludge communities are the protozoa which feed upon the bacteria. About 230 species have been reported to occur in activated sludge, and they may constitute as much as 5 percent of the mass of biological solids in the system. Ciliates are usually the dominant protozoa both numerically and from biomass estimations. All but one of them are known to feed on bacteria, and the most important ones are either attached to or crawl over the surface of sludge flocs. On occasion, both amoebae and flagellates may be seen in small numbers, but they are not thought to play a major role in good settling, stable communities. It has been suggested that protozoa play a role in the formation of sludge flocs and contribute to the absence of dispersed bacteria in stable communities.

Nuisance organisms are those which interfere with the proper operation of the process when present in sufficient numbers. Most problems arise with respect to sludge settling and are the result of filamentous bacteria and fungi. If only a small percentage by weight of the community is made up of filamentous organisms, the effective specific gravity of the sludge flocs is reduced so much that the sludge is very difficult to separate by gravity settling. This leads to a situation known as bulking.

A properly operated activated sludge process will provide the conditions necessary to encourage the development of the beneficial organisms and to discourage growth of the nuisance organisms.

3.2.6.1 Steps in the Activated Sludge Process

1. Mixing the Activated Sludge with The Incoming Waste. It is very important that the returned activated sludge (RAS) be thoroughly mixed with the incoming waste. The initial mixing is usually accomplished in one of the following ways.

   In a conventional activated sludge process, the RAS and incoming waste are mixed at the inlet to the aeration tank. The agitation provided by the turbulence in the inlet pipes or channels usually provides the initial mixing.

   In a complete mix activated sludge process, the RAS and the incoming waste are mixed in a line or channel and introduced to the aeration tank at various points throughout the length of the tank. Mixing occurs in the line as the liquid travels to its introduction point.

   In a step aeration activated sludge process, the RAS is introduced at the inlet of the aeration tank. The incoming waste is introduced at several points along the length of the aeration tank. Initial mixing occurs within the aeration tank itself.

2. Aeration and Agitation of the Mixed Liquor. Aeration and agitation of the contents of the aeration basins are necessary to further mix the RAS with the incoming waste, keep the sludge in suspension, and supply oxygen required for biological oxidation.

   The degree of mixing within an aeration system exerts a profound effect upon the degree of removal of organic compounds within these aeration basins. The microorganisms are limited in their ability to seek out their food, and mixing brings the organic matter into contact with these microorganisms. Good mixing also decreases the chances of localized differences of temperature or nutrient concentrations occurring within the aeration basin.

   If mixing is too vigorous, it is possible that the floc particles that form within these aeration basins can be "sheared" or separated, and the settling ability of the sludge in the secondary clarifiers could be impaired. If mixing is not vigorous enough, settling of solids may occur in the aeration basin. Also, good contact between the organic matter and the microorganisms will not be accomplished.

   Aeration and agitation of the mixed liquor are generally accomplished through one of two methods: subsurface diffused air or mechanical aeration. In a

diffused air system, compressed air is introduced at the bottom of the tank. This causes the contents of the tank to be circulated by the air-lift effect. Two types of diffused air systems are usually found in aeration systems: coarse bubble and fine bubble. Fine bubble diffusers provide for more surface area for air-liquid contact, while large bubble diffusers generally present less operational problems such as clogging.

There are several types of mechanical aeration devices. Floating or fixed platform surface aerators are common. Most use blades to agitate the mixed liquor, and some utilize an updraft or downdraft pump or turbine. Also in use are submerged turbine aerators and horizontal rotating brush aerators. All these mechanical aeration devices serve to mix the liquid and entrain air bubbles in it.

The basic oxygen requirement is that there shall be sufficient oxygen added to the system to maintain at least 2 ppm of dissolved oxygen in all parts of the system under all loading conditions. The degree of treatment of the influent waste depends on how many microorganisms there are in the aeration system and how well these organisms work. In any activated sludge system, these organisms require an aerobic environment, that is, the presence of dissolved oxygen. As the supply of food (organic matter) to the aeration system is increased, the microorganisms will increase their activities and will demand more oxygen. If the supply of oxygen does not keep pace with the demand, septic or anaerobic conditions may occur.

Extremely high oxygen residuals (9 ppm to 10 ppm) are not beneficial to the system and can sometimes lead to problems. Besides wasting oxygen, such high concentrations of dissolved oxygen can sometimes cause "bubbles" to be carried over into secondary clarifiers and hinder settling in these tanks.

3. Separation of Activated Sludge from the Mixed Liquor. Before the treated waste can be discharged into receiving waters, the activated sludge must first be removed. This is done in secondary or final sedimentation tanks called clarifiers. The cycle of sludge removal from these secondary clarifiers is much more important than with primary tanks. Some sludge is being removed continuously to be used as return sludge in the aeration tanks. This return

sludge must be removed before it loses its activity because of the death of aerobic organisms resulting from the lack of oxygen at the bottom of the tank.

It is good practice to operate final clarifiers with a sludge inventory as small as possible. Minimizing sludge may be accomplished by removing solids at the same rate as they are applied. If solids output does not equal input, solids will accumulate in the final settling tank and will eventually spill over the effluent weir. As a result of solids accumulating in secondary clarifiers:

- Solids become thick and difficult to remove from the bottom;
- Portions of the sludge blanket could become anaerobic;
- MLSS concentration of the system will drop;
- Septic sludge gives off gases which could cause sludge to rise.

4. Return of Proper Amount of Activated Sludge. So that the biological solids do not accumulate in the secondary clarifiers, they must be removed at an average rate to that at which they are applied. It is necessary to return this sludge as rapidly as possible, with the least amount of water, to the head of the aeration basin. If the return rate is too slow, there will be insufficient bacteria in the aeration tank to effectively reduce the organic material. If the rate is too high, settling characteristics of the sludge will be impaired.

5. Wasting of the Excess Activated Sludge. The objective of wasting activated sludge is to maintain a balance between the microorganisms and the amount of food such as total organic carbon (TOC) or chemical oxygen demand (COD). It is known that when the microorganisms remove organic matter from the wastewater, the amount of activated sludge increases. It has been estimated that under normal operating conditions about 1/3 of the usable organic matter is used for oxidation while the remaining 2/3 are used for synthesis. Large portions of the incoming waste are inert and not easily used. The result is that much of the substrate removed by the sludge remains in the floc and accumulates as either inert or living solids.

   The objective of sludge wasting is to remove just that amount of microorganisms that grow in a period. When this is done, the amount of

activated sludge formed by the microorganisms growth is just balanced by that which is removed from the process. This, therefore, allows the total amount of activated sludge in the process to remain somewhat constant.

This condition is called "steady-state," which is a desirable condition for operation. However, "steady state" can only be approximate because of the variations in the nature and quantity of the food supply and of the microorganism population.

Wasting of the activated sludge can be done on an intermittent or continuous basis. Intermittent wasting has one advantage in that less variation in sludge concentration will occur during the waste period and the amount of sludge wasted will be more accurately known. The disadvantages of intermittent wasting are that the sludge handling process may be overloaded and that the activated sludge process is out of balance for a period of time.

3.2.6.2 Activated Sludge Flow Models

The two types of flow models referred to in activated sludge treatment are complete mix and plug flow.

1. Complete Mix Flow. In complete mix flow arrangements, the influent waste, mixed with the return sludge, is rapidly distributed throughout the basin, and operating characteristics are identical throughout the basin. An important factor in complete mix flow patterns is that the process can handle surges in organic loading without adversely affecting effluent quality.

2. Plug or Series Flow. The plug flow arrangement is the oldest and most widely used form of reactor basin. One of the characteristics of the plug flow configuration is a very high organic loading in the inlet section of the basin. The loading is then reduced as the organic material in the raw wastewater is oxidized. As the complete mix configuration is noted for its ability to assimilate shock loads, plug flow reactors are able to avoid "bleed through," or the passage of untreated materials during peak flows.

3.2.6.3 Factors Affecting the Activated Sludge Process

The factors previously discussed which affect biological processes (pH, temperature, nutrients, oxygen supply, and shock) all apply to the activated sludge process. In addition, several other factors must be considered.

1. Detention Time. It is commonly thought that the removal of organic matter in the activated sludge process takes place in two steps: the removal of organic matter from the wastewater by the sludge floc and the digestion of the organic material by the microorganisms in the floc.

   The sludge floc is formed by mutual coagulation of bacteria with other suspended and colloidal matter. The floc gradually increases to a maximum size. The size depends on how much movement through the water the floc particles can stand without breaking apart (shearing). As the sludge floc moves through the aeration tank, it collides with the suspended and colloidal particles, which then adhere to or adsorb onto the floc. This process is called adsorption. As the floc travels through the basin it will also absorb soluble organic matter, allowing it to pass through the cell wall into the cell. This is called absorption. Adsorbed food matter must be broken into a simple soluble form before it can be absorbed into the cell. The adsorption process occurs very quickly in activated sludge treatment processes, usually requiring only 15 to 30 minutes to occur. But the process of absorption, converting this organic material to carbon dioxide, water, and more activated sludge, requires a longer period of time. As the microorganisms use the sorbed material the sorptive sites are reopened, allowing more waste material to be trapped by the floc. The process of digesting this organic material must be completed before the organisms leave the aeration system. The aeration tank is sized to provide enough detention time to accomplish the treatment required.

2. Dissolved Oxygen Residual. As previously stated, all aerobic biological processes require an oxygen supply. Proper control of the activated sludge process requires that a residual of at least 2.0 mg/l of dissolved oxygen (DO) is maintained in the aeration basins at all times. Residuals below this point can cause shifts in the predominate species of organisms within the system and may encourage the growth of filaments. Maintaining a DO of 2.0 mg/l is

recommended, not because the higher DO levels affect the process in any way, but only because it offers a degree of protection against large increases in organic loadings that may enter the process. Carrying too high a DO level can result in wasted energy (unnecessary cost). The upper limit of DO residuals should be in the range of 5 to 7 mg/l. The secret to control of dissolved oxygen in an aeration system is to carefully monitor all parameters as they enter the aeration system and adjust the DO as needed. As heavy organic loads arrive at the aeration system, the DO residuals should be monitored on an hourly basis as the change in organic loading takes place. DO residual tests should be run hourly until the change has been completed. As increases in organic loadings take place, it is only necessary to maintain DO levels above 2.0 mg/l at all times. Instantaneous drops in DO residuals to points slightly below 2.0 mg/l at the peak of a change are no cause for alarm. If the process DO residual recovers immediately (within 2 hours) and holds, no action is required. Consistent drops in DO residual below 1.0 mg/l in a 24 hour period can cause problems and corrective action must be taken.

3.2.6.4 Operational Parameters

There are a number of operating parameters important to the operation of activated sludge process. It must be noted that these operating parameters are provided for reference only. Each individual treatment system will have its own unique operating characteristics.

1. Mixed Liquor Suspended Solids (MLSS). This is a very important measurement and shows the amount of activated sludge inventory. It is recommended that the MLSS be determined on a daily basis.

2. Mixed Liquor Volatile Suspended Solids (MLVSS). This test indirectly shows the active biological fraction of mixed liquor solids and directly tells the amount of inert solids. For example, MLVSS will typically be 70 to 80 percent of the total MLSS. However, during times of heavy infiltration of the sewer system, the carryover of silt into the aeration basins may decrease the MLVSS to 55 to 60 percent. When the percent of MLVSS decreases, the total MLSS must be increased to maintain the same level of active organisms. It is recommended that the MLVSS be determined on a daily basis.

3. Food to Microorganism Ratio (F/M). This parameter is used to express the total loading of organics on the biological system. It is the ratio of pounds of BOD5 entering the aeration basin per day to the pounds of MLVSS in the aeration basin and the secondary clarifier.

   A high F/M reflects a high loading on the activated sludge system which will result in more waste activated sludge generated per pound of BOD removal. A very high F/M (above 0.5) indicates a more unstable system.

   A low F/M (less than 0.1) at normal MLSS concentrations indicates a lightly loaded activated sludge plant. The waste sludge should be stable and may not require any added digestion.

   F/M ratio is calculated as:

$$\frac{(\text{Aeration Influent BOD, mg/l})(\text{Influent Flow Rate, MGD})\quad(8.34)}{(\text{MLVSS Concentration, mg/l})(\text{Aeration Basin Volume, MGD})\quad(8.34)}$$

4. Sludge Age (MCRT, SRT) is the average length of time the activated sludge solids are in the system. Sludge age is an important parameter, because the amount of time that the microorganisms are given to breakdown the waste products has a significant effect on effluent quality. SA is calculated as:

$$\frac{(\text{MLVSS Concentration, mg/l})(\text{Aeration Basin Volume, MG})\quad(8.34)}{[(\text{Return Sludge VSS,mg/l})\text{x}(\text{Waste Sludge Flow MGD})\text{x } 8.34][(\text{Effluent VSS,mg/l})\text{x}(\text{Effluent Flow, MGD})\text{x } 8.34]}$$

5. Sludge Density Index (SDI). The rate that activated sludge solids settle to the bottom of a final settling tank depends on the settling characteristics of the sludge. These characteristics are determined by a simple settling test, the results of which can be used to determine the SDI. A 1,000 ml sample is collected from the aeration tank and allowed to settle for 30 minutes in a 1,000 ml graduated cylinder. The volume of settled sludge is read at the end of the 30 minutes.

$$\text{SDI} = \frac{\text{MLSS (mg / l)}}{\text{ml of settled sludge after 30 min settling x 10}}$$

A good Sludge Density Index is about 1.0. A sludge with an index of 1.5 is dense and settles quickly. An index of less than 1 means a lighter sludge which settles slowly.

6. Sludge Volume Index (SVI). This index is also used to reflect the settling characteristics of activated sludge, but is defined as:

$$SVI = \frac{\text{ml of settled sludge after 30 min settling x 1,000}}{\text{MLSS (mg/l)}}$$

In this case, the lower the SVI, the more dense the sludge. An SVI of 100 or less is generally considered a good settling sludge.

7. Microscopic Examination. Microscopic examination of the MLSS can be a significant aid in the evaluation of the activated sludge process. The presence of various microorganisms within the sludge floc can rapidly indicate good or poor treatment. Protozoa play an important role in clarifying the wastewater and act as indicators of the degree of treatment. The protozoa eat the bacteria and help to provide a clear effluent. The presence of rotifers is also an indicator of effluent stability. A predominance of protozoa (ciliates) and rotifers in the MLSS is a sign of good sludge quality. The presence of filamentous organisms and a limited number of protozoa is characteristic of a poor quality activated sludge. This condition is commonly associated with a sludge that settles poorly.

3.2.6.5 Total Solids Inventory Approach

This technique for process control is used by many operators because it is simple to understand and involves a minimum amount of laboratory control. The MLSS control technique usually produces good quality effluent as long as the incoming wastewater characteristics are fairly constant with minimal variations in influent flow and organic loading rates.

With this technique, the operator tries to maintain a constant MLSS concentration in the aeration tank to treat the incoming wastewater organic load. To put it in simple terms, if it is found that a MLSS concentration of 2,000 mg/l produces a good quality effluent, the operator must waste sludge from the process to maintain that concentration.

If the MLSS level increases above the desired concentration, more sludge is wasted until the desired level is reached again.

When using the total solids inventory approach for process control, the operator should take into account the volume of solids in the aeration tank and in the clarifier, if a significant blanket level is normally maintained.

3.2.6.6 Sludge Age As A Control Parameter

Sludge age, or Mean Cell Residence Time (MCRT), is a process control technique available to the plant operator. Basically, the sludge age expresses the average time that a microorganism will spend in the activated sludge process. The sludge age value should be selected to provide the best effluent quality. This value should correspond to the loading for which the process is designed. The operator must find the best sludge age for his process by relating it to the organic loading as well as the effluent COD, BOD, and SS concentrations.

This is an important parameter because the amount of time that the microorganisms are given to break down the waste products has a significant effect on effluent quality. Generally speaking, sufficient time must be permitted for the microorganism to be in contact with the waste to accomplish treatment. If too little time exists, the biological system may have insufficient time to degrade the wastes, resulting in poor quality effluent. If too much time is allowed, the microorganism will deplete the food supply available and begin to die off, resulting in a higher fraction of nonactive biological material in the sludge and a resultant loss of "fine" solids in the effluent. Sludge age also directly affects solids settling in the secondary clarifier. A young sludge is generally in a high growth rate phase which results in a dispersed growth biological population characterized by poor settling. An old sludge is characterized by low activity and dense floc which settles rapidly with little filtering action as it settles.

The data required for calculating sludge age is as follows:

- Aeration basin MLSS, mg/L
- Aeration basin volume, MG
- RAS SS, mg/L

- Effluent flow, MGD
- Effluent SS, mg/L
- WAS flow, MGD

The determination of the proper target sludge age for the process at any one time is the greatest challenge for the operator. The operator must determine the best sludge retention time for his process by using best judgment in the interpretation of results from other process indicators such as observations of the aeration tanks and clarifiers, as well as final effluent quality. That sludge age which gives the best results will change during the year in relation to external influences such as temperature. Longer sludge ages will be needed in colder weather when the bacterial culture is less active. At this time you will need more bacteria to do the same amount of work.

The operator should make his changes in sludge age slowly and cautiously and only change the sludge age one day at a time. Personnel should not increase or decrease the wasting rate more than 15 percent from one day to the next. Allow at least three sludge ages to let the process settle down before determining the extent of change in the process that has taken place from a one day's change in sludge age before making any further changes. In other words, it takes three sludge ages for the process to reach a steady state after a one-day change in sludge age.

3.2.6.7 Establishment Of Desirable MLSS Ranges

As stated above, the determination of a desirable sludge age or solids inventory level is based on a number of factors, including organic loading, effluent standards, and seasonal variables. Generally, MLSS levels are maintained at lower concentrations in the summer and higher concentrations in the winter.

The lower MLSS levels in the summer months are related to the increased activity of the microorganisms at higher temperatures. During the winter months, the activity of the microorganisms is lower, requiring more biomass to treat the incoming waste.

MLSS levels should also take into consideration the organic loading to the treatment plant. Higher organic loadings to the plant will require a higher MLSS level to

assimilate the incoming waste. For this reason, food to microorganism ratio (F:M) should be calculated for the treatment plant on a regular basis.

3.2.6.8 Monitoring Sludge Blanket Depth

Monitoring the depth of the sludge blanket in the clarifier is the most direct method available for determining the RAS flow rate. The blanket depth should be kept to less than one-fourth of the clarifier sidewall water depth. The operator must check the blanket depth on a routine basis, making adjustments in the RAS to control the blanket depth.

If the depth of the sludge blanket is increasing, an increase in the RAS flow can only solve the problem on a short-term basis. Increases in sludge blanket depth may result from having too much activated sludge in the treatment system, and/or because of a poorly settling sludge. Long-term corrections must be made that will improve the settling characteristics of the sludge or remove the excess solids from the treatment system. If the sludge is settling poorly due to bulking, the environmental conditions for the microorganisms must be improved. If there is too much activated sludge in the treatment system, the excess sludge must be wasted.

Measurements of the sludge blanket depth in the clarifier should be made at the same time each day (or each shift). The best time to make these measurements is during the period of maximum daily flow because the clarifier is operating under the highest solids loading rate. The sludge blanket should be measured daily, and adjustments to the RAS rate can be made as necessary. Adjustments in the RAS flow rate should only be needed occasionally if the activated sludge process is operating properly.

An additional advantage of monitoring the sludge blanket depth is that a problem, such as improperly operating sludge collection equipment, will be observed due to irregularities in the blanket depth. A plugged pickup on a clarifier sludge collection system would cause sludge depth to increase in the areas where the improperly operating pickups are located.

3.2.6.9 Sludge Wasting Strategy

Control of an activated sludge process is achieved through the wasting of excess sludge from the system. Success or failure in operating an activated sludge plant depends on proper control of the mass of active organisms in the plant. The objective of wasting activated sludge is to maintain a balance between the microorganisms and the amount of food as defined by tests such as chemical oxygen demand (COD) or biochemical oxygen demand (BOD). It is known that when the microorganisms remove BOD from wastewater, the amount of activated sludge increases (microorganisms grow and multiply). The rate at which these microorganisms grow is called the growth rate and is defined as the increase in the amount of activated sludge that takes place in one day. The objective of sludge wasting is to remove just that amount of older microorganisms equal to the new growth. When this is done, the amount of activated sludge formed by the microorganism growth is balanced by that which is removed from the process. This therefore allows the total amount of activated sludge in the process to remain somewhat constant. This condition is called "steady-state" which is a desirable condition for operation. However, steady-state can only be approximated because of the variations in the nature and quantity of the food supply (BOD) and of the microorganism population.

Wasting of the activated sludge is normally accomplished by removing a portion of the RAS flow. An alternate method for wasting sludge is from the mixed liquor in the aeration tank. There is a much higher concentration of suspended matter in the RAS than there is in the mixed liquor. Therefore, when wasting is practiced from the mixed liquor, larger sludge handling facilities are required. Wasting from the RAS takes advantage of the gravity settling and thickening of the sludge that occurs in the secondary clarifier. However, wasting from the mixed liquor has the advantage of not wasting an excessive mass of sludge because of the lower concentration of sludge involved.

Wasting of the activated sludge can be done on an intermittent or continuous basis. The intermittent wasting of sludge means that wasting is conducted on a batch basis from day to day.

Intermittent wasting of sludge has the advantage that less variation in the waste sludge concentration will occur during the wasting period, and the amount of sludge wasted will be more accurately known. The disadvantages of intermittent wasting are

that the sludge handling facilities in the treatment plant may be loaded at a higher hydraulic loading rate and that the activated sludge process is out of balance for a period of time until the microorganisms regrow to replace those wasted over the shorter period of time.

It is the objective of process control to approach a particular steady state in the activated sludge system. Proper control of the WAS will help provide this steady state while producing a high quality effluent with minimum operational difficulties.

3.2.6.10 Oxygen (DO) Uptake Rate

A simple, but valuable, test the operator can use to monitor the status of the plant is the DO uptake rate test. This is a quick and easy procedure that allows the plant operator to assess the activity of the microorganisms in his biological system. By measuring the rate at which DO is used in a sample of mixed liquor collected from the aeration basin and comparing the results with normal readings for the plant, the operator can determine if the microorganisms are more active than usual or if they are being inhibited.

The plant operator should measure the DO uptake rate in the aeration basin each day so that a "typical" uptake rate for the treatment plant can be identified. This normal value should be established based on readings taken during times when the plant is operating efficiently. An uptake rate lower than normal would indicate low activity, and a high rate would indicate high activity. A low uptake rate in the aeration basin is an indication of impending problems. Lower than normal influent BOD loadings, too low or high a pH, low DO levels, or the presence of toxic material will cause low DO uptake rates. A high oxygen uptake rate indicates higher BOD loadings to the plant than usual. The DO uptake test can be used as a tool to alert the operator of impending problems and give him time to make the necessary adjustments before the performance of the plant is adversely affected.

3.2.6.11 Oxygen Uptake Rate Determination

A. General

This test measures the rate at which activated sludge organisms use available oxygen.

B. Apparatus

1. DO meter with membrane probe.

2. BOD bottles.

3. Stopwatch or timepiece.

4. Magnetic stirrer and stir bars.

5. Necessary assorted glassware.

C. Procedure

1. Calibrate meter according to manufacturer's instructions.

2. Shake freshly collected sample vigorously in bottle with air space to increase the DO concentration.

3. Place a stir bar into the bottom of a BOD bottle. Pour sample to overflowing in bottle. Insert DO probe and place bottle on magnetic stirrer with vigorous stirring.

4. When DO reading stabilizes, read and record initial DO and start timer. Record DO readings at intervals of 1 minute. Read and record DO for 15 minutes or until DO drops to 1.0 mg/l DO.

D. Calculations

$$\text{Oxygen Uptake Rate (OUR)} = \frac{\text{DO initial - DO final}}{\text{time interval}} \quad \text{x} \quad 60\ \text{(min/hr)}$$

3.2.6.12 Settleability Tests

One of the best process monitoring tools available to the operator is the 30-minute settling test. This test is valuable because it not only helps the operator determine if his plant is running efficiently, but, if problems do exist, it also can help him locate the source of those problems. This is extremely important and time-saving to the operator because once he knows the problem source, he can concentrate his efforts on conducting tests and investigating probable problem causes which are specific to that area of the plant.

For instance, if during the 30-minute settling test the MLSS settle well in the 2-liter settleometer, but are not settling well in the clarifier, then the problem is probably in the clarifier. Poor settling in the clarifier could be caused by too high a sludge blanket, denitrification, equipment malfunction, etc. On the other hand, if the MLSS do not settle well in the 30-minute settling test, then you wouldn't expect them to settle well in the clarifier, and the problem area is probably the aeration basin. Some typical problems specific to the aeration basin include high DO levels, nitrogen or phosphorous deficiency, low pH, low DO, improper F/M ratio, high BOD loadings, etc. The 30-minute settling test is a reasonable approximation of what is happening in the secondary clarifiers. Through careful observation of the settling rate and sludge quality, the operator can identify problems which may be occurring in the system. Among the types of final clarifier settling problems the 30-minute settling test can help identify are:

Type	**Symptoms**	**Cause**
Sludge Bulking	Large floc distributed throughout the clarifier; poor compaction in sludge blanket; microexam indicates predominance of filamentous organisms	Organic overloading, incorrect F/M ratio, nutrient (N)(P) deficiency
Sludge Rising	Biological solids refloat to the clarifier surface after settling to the bottom	Too long sludge detention time in clarifier, resulting in gas formation due to septicity and/or denitrification
Deflocculation	Small, buoyant floc; turbid supernatant	Toxicity, nutrients deficiency, organic shock loads, anaerobic conditions
Straggler Floc	Small, light floc; clear supernatant	Low sludge age
Pin Floc	Small, dense floc, turbid effluent, rapid settling floc	High sludge age

3.3 SECONDARY CLARIFICATION

3.3.1 Introduction

Clarification refers to any of several treatment processes which are used to remove suspended solids particles from the wastewater. The removal of suspended solids can be important for at least three reasons. First, most treated wastewater discharges are permitted with strict limits on the amount of suspended solids that the effluent can contain so as to reduce the environmental impact of these solids (such as excess siltation in receiving streams). Second, many of the suspended solids in wastewater are organic in nature and will cause a higher oxygen demand (biochemical or chemical) in the effluent or subsequent treatment processes unless they are removed. And third, the presence of large amounts of suspended solids can cause problems in downstream treatment processes, including the sedimentation and accumulation of solids in tanks, channels, or pipelines.

For these reasons, gravity clarifiers are often used at the beginning, end, and sometimes even the middle of process trains for wastewater treatment. These solids removal units are sometimes referred to as primary, secondary, tertiary, or final clarifiers, depending on their location and function in the treatment system. Basically, the purpose and operation of each of these units is the same, although the settling characteristics of the solids to be removed are often quite different. Since the settling characteristics of solids particles will vary with the wastewater and the treatment system, the operation of a clarification unit should be based on an understanding of the theory of the gravity clarifiers and the variables which affect their efficiency. The MacDill AFB WWTP utilizes secondary clarifiers.

3.3.2 Theory of Operation

Most of the suspended solids particles present in wastewater have a density that is either greater or less than that of water. As a result, these solids will tend to either sink or float under quiescent (still) conditions. It is for this reason that wastewater collection and treatment systems are designed to insure a turbulent flow of wastewater that will keep these solids particles in suspension until they reach an appropriate solids removal process, such as a grit chamber or gravity clarifier. A gravity clarifier is simply a large volume tank that is designed for efficient solids removal. It includes a system for the

withdrawal of settled or floating solids, and it often has baffles and weirs to ensure that quiescent conditions exist and to minimize any short-circuiting that would reduce solids removal efficiency. Clarifiers are designed to remove a large portion of those particles that have been allowed to pass through grit chambers.

For purposes of discussion, clarifiers are said to have four zones: inlet, clarification, sludge, and outlet. The liquid to be clarified is admitted to the tank through the inlet zone. Separation of the solids from the liquid takes place in the relatively quiescent clarification zone. The clarified effluent is then removed through the outlet zone. Separated solids are allowed to accumulate, compact, and are then withdrawn from the sludge zone.

As previously mentioned, suspended solids are removed in a gravity clarifier by virtue of the difference between their density and that of the surrounding wastewater. Density simply refers to the weight of an object or a material that has a known volume. For example, the density of pure water at 60°F is approximately 62.4 pounds/cubic foot. Sometimes density is expressed using another term, called specific gravity. The specific gravity of a material is equivalent to its weight divided by the weight of an identical volume of pure water. Pure water has a specific gravity of 1.0 by definition. Therefore, an object that has a density of 124.8 pounds/cubic foot (twice that of pure water) would have a specific gravity of 2.0. Regardless of how it is expressed, any object with a specific gravity (or density) greater than water will tend to sink, while an object that is less dense than water (specific gravity less than 1.0) will tend to float. And, of course, a particle that has the same density as water (that is, it weighs the same amount as the water it displaces) will neither sink nor float.

The rate at which solids particles settle (or float) depends on the amount of difference between their density and that of the wastewater. Particles that have a density much greater than water will settle more rapidly than those with a density only slightly greater than water. Likewise, a particle that is slightly less dense than water will rise more slowly than a particle that is much less dense than water. This is an important consideration, since many of the settleable suspended solids particles typically found in wastewater treatment plants are only slightly more dense than water. The specific gravity of these particles is often within the range of 1.00 to 1.05. At the same time, there may also be solids present that have specific gravities much greater than water (in

the range of 1.1 to 2.0) which will rapidly settle out and accumulate in process tankage and piping upstream of clarification, unless turbulent flow conditions are maintained.

Two other factors affect the rate of solids settling (or floating). These are (1) particle size, or mass, and (2) particle shape. In general, a larger particle (that is, one having a greater mass) will sink or rise faster than a smaller particle having the same density. Some particles, called colloids, are in fact so small that they cannot be separated from water using gravity alone and must first undergo coagulation and flocculation to increase their size so that they can be removed in a gravity clarifier.

In addition to particle size, the shape of a particle is also important. A particle that is perfectly spherical in shape will settle faster than a particle made of the same material and having the same mass (total weight) that is more irregularly shaped. The reason for this is that there is more drag or friction created by irregularly shaped particles as they settle through water, which tends to slow descent. As an example of this, imagine two identical pieces of paper that are dropped to the floor. Both pieces will fall in about the same amount of time. However, if one piece of paper is tightly wadded up and the other is lightly crumpled, the tightly wadded piece will fall faster than the lightly crumpled piece, even though they have the exact same mass and density. The reason for this is that the lightly crumpled piece of paper is subject to more friction or drag when falling through the air, which makes it fall more slowly.

To summarize, suspended solids particles can be separated from wastewater under the force of gravity by virtue of the difference between their densities and that of the wastewater. The rate at which these particles settle (or rise) depends on the magnitude of this density difference as well as upon the size (mass) and the shape of the solids particles. Therefore, any factors which change the relative densities of the suspended solids particles and the wastewater, or any factors which change the size or shape of the solids particles, will affect the rate of solids settling during gravity clarification. The settling rate (expressed in terms such as feet per hour) is important since it determines how well the clarifier will perform. It shows what fraction of the influent suspended solids will be captured and removed.

A factor which greatly affects settling rate is hydraulic residence time. Imagine a solids particle that settles at a rate of 10 feet per hour under quiescent conditions. If this

particle were placed into a tank of water near the surface, it would settle at a constant rate of 1 foot every 6 minutes (10 feet/hour) until it reached the bottom of the tank. If the tank contained 10 feet of water, this would take 1 hour or less, depending on the original depth at which the solids particle was placed into the tank.

Now imagine the same particle being placed into one end of a 200-foot long tank in which water is flowing horizontally at a constant rate of 2 feet per minute. (For this discussion, we will ignore effects of the inlets and outlets to the tank and assume that the flow is perfectly distributed from top to bottom and that it travels only horizontally). At this flow rate, we can assume that the water in the tank is not turbulent enough to keep the particle in suspension and that the particle will still settle at a rate of 10 feet/hour. What occurs is illustrated in Figure 3.1. It will take 100 minutes (200 feet divided by 2.0 feet/minute) for the water to travel through the tank. If, during its diagonal course of travel, the particle settles vertically toward the bottom of the tank at a rate of 1.0 foot in 6 minutes, it will rest on the floor of the tank in 60 minutes if the tank is 10 feet deep. In other words, if the particle settles at the rate of 10 feet in 60 minutes, it should settle in the first 120 feet of the tank.

Now consider that the horizontal flow rate is doubled to 4.0 feet per minute, as shown in Figure 3.1b. In this case, it will only take 50 minutes for the water to pass through the tank. If the same particle enters the tank at the water surface, it will not have time to settle to the bottom of the tank before it reaches the other end, because its vertical settling velocity is only 10 feet per 60 minutes and the tank is 10 feet deep.

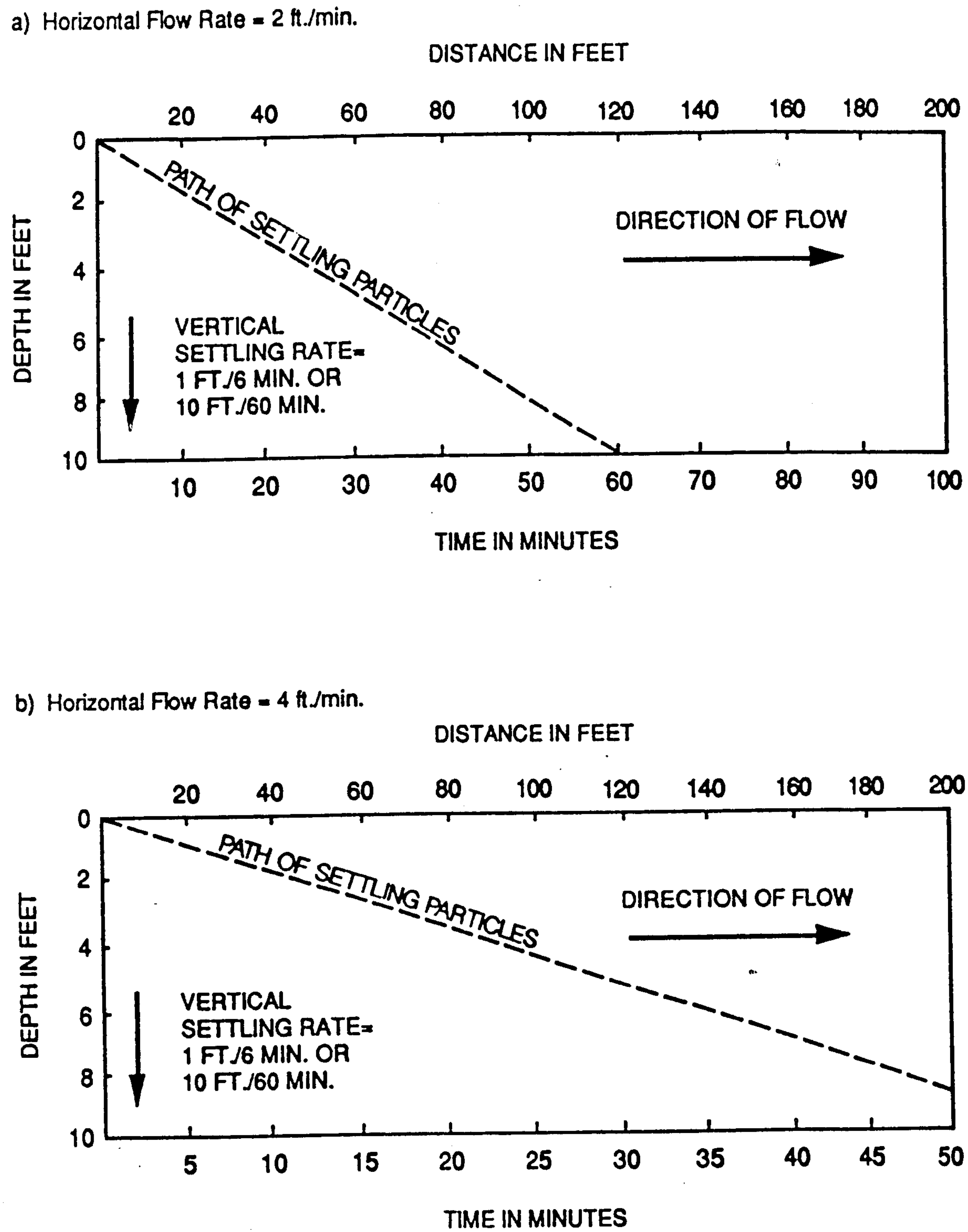
From the previous discussions, it should have been obvious that hydraulic residence time (HRT) has an important effect on whether a particle with a given settling rate will be captured or not. In general, with a longer residence time, more of the slower settling particles will settle out.

3.3.3 Density Currents

Short-circuiting can occur in settling basins if the incoming flow has a higher temperature or density than the mass of liquid in the basin. This condition is usually evidenced by violent rolling of masses of liquid with entrained solids to the surface.

Figure 3.1

IDEALIZED PARTICLE SETTLING IN A GRAVITY CLARIFIER



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Short-circuiting can occur when the temperature suddenly increases 1° to 2°F with light flocculant-type solids. If the incoming flow is colder than the water in the basin, it can flow along the bottom at a high velocity and reduce the efficiency of solids removal.

3.3.4 Operating Parameters

There are a number of operating parameters important to the efficient operation of clarifiers.

3.3.4.1 Hydraulic Loading

Hydraulic loading on a clarifier is generally measured in terms of surface loading rate. Surface loading rate is defined as the average influent flow (gallons per day) divided by the surface area of the clarifier. It is a measure of the upward velocity of flow and must be kept low enough to prevent flow of sludge over the weirs. Surface loading rate is calculated as:

$$\text{Surface Loading Rate, GPD / ft2} = \frac{\text{Influent Flow Rate, GPD}}{\text{(Clarifier Surface Area, ft2)}}$$

Secondary clarifiers will operate efficiently when the loading rate is in the range of 400-800 gpd/ft^2.

3.3.4.2 Detention Time

Detention time is defined as the average time a particle of water is in the clarifier. Detention time is calculated as:

$$\text{Detention Time, hrs} = \frac{\text{(Clarifier Volume, Gal)(24Hrs / Day)}}{\text{Influent Flow Rate, GPD}}$$

Secondary clarifiers will operate efficiently when the detention time is between 1.5 and 2.5 hours. If detention time is too short, a smaller portion of the suspended solids will settle, and removal efficiency will decline. If detention time is too long, removal efficiency will not improve materially and can lead to wastewater becoming septic in the clarifier.

3.3.4.3 Weir Overflow Rate

Weir overflow rate is defined as the average influent flow (gal/day) divided by the weir length. It should be kept low enough to provide quiescent conditions in the clarifier.

Weir overflow rate is calculated as:

$$\text{Weir Overflow Rate, GPD / ft} = \frac{\text{Influent Rate, GPD}}{\text{(Weir Length of Clarifier, ft)}}$$

Weir loadings of secondary clarifiers will generally be around 10,000 GPD per linear foot.

3.3.4.4 Solids Removal

Solids must be removed from clarification tanks or, eventually, the settled sludge level will increase to the point that solids are washed out with the tank's effluent. Solids may be removed continuously or in a batch method. Solids which settle in secondary clarifiers are sometimes removed continuously and sometimes in batches depending on the plant size and type of treatment process.

3.4 FILTRATION

Filtration is a separation process used to remove suspended solids present in the wastewater. In the filtration process, wastewater is passed through a bed of porous material which separates the solids from the wastewater. Generally, filtration is used after clarification to further reduce suspended solids concentrations in the final effluent. In deep granular filters, the solids are removed through an adsorption/disposition process as the wastewater passes through a deep bed of granular material. In precoat and cartridge filters, the solids are removed through a mechanical straining process as the wastewater passes through a thin layer of filter media.

3.4.1 Theory of Operation

Filtration involves the passage of water through porous media with a resulting removal of suspended solids. A number of mechanisms, some chemical and some physical, are involved in the solids removal process. The predominant mechanisms are straining, disposition, and adsorption. The dominant mechanism for a given filter depends upon the physical and chemical characteristics of the wastewater and the filter.

Straining involves removal of particles, either at the filter surface or within the interstices of the filter media, and is affected by the filter media and particle size and the filtration rate. For both precoat filters and cartridge filters, the predominant removal mechanism is assumed to be straining, which occurs at the surface of the filter media. Although straining also occurs to a limited degree in deep granular filters, primarily within the interstices of the media, its importance is generally minimized during design because it leads to rapid buildup of head loss which limits the length of filter runs.

Disposition and adsorption within the filter bed are the predominant solids removal processes in deep granular filters. Disposition involves gravitational settling, diffusion, and interception and is affected by the physical characteristics and the size of the media, the filtration rate, the fluids temperature, and the size and density of the suspended solids. Adsorption relies upon the attachment of the suspended solids particles to the filter media. The amount of surface available for adsorption is enormous, roughly 3,000 to 5,000 square feet per cubic foot of media. Adsorption relies upon attachment and is affected by use of coagulants, the characteristics of the wastewater (especially particle

size), shear strength and driving force, adhesiveness of the suspended solids floc, and the characteristics of the filter media.

3.4.2 Driving Force

There are three basic filter operating methods, and they differ in the way that the driving force is applied across the filter. These methods are referred to as constant-pressure filtration, constant-rate filtration, and declining rate filtration. For constant-pressure filtration, a constant driving force is applied across the filter for the entire filter run. Because filter resistance is lowest at the start, the flow rate is at its peak. As solids are captured, filter resistance increases and the rate of flow decreases. This operating method is seldom used because a large flow equalization basin is required to deal with the change in flow during the filter run.

In constant-rate filtration, a constant pressure is applied to the filter, but filter resistance is modulated through control of the flow rate using a flow control valve. At the start of the filter run, the flow control valve is nearly closed, then as solids accumulate, the flow control valve is opened to compensate for the increase in the filter resistance. While storage capacity is minimized, the initial and operating costs for the rate controller are high and water quality is lower than with declining rate filtration. The constant rate system is also wasteful of available head because excess head is lost in the controller. Additionally, the control valve may set up high frequency surges in the filter bed.

Declining-rate filtration utilizes a bank of filters to moderate the effect of increases in filter resistance. As the filters served by a common header become dirty, the flow through the dirtiest filter drops rapidly, increasing the driving force so that the other filters can handle additional flow from the dirtiest filter. This method provides a more gradual decrease in the rate of flow over the filter cycle and provides a better effluent quality than with constant rate operation. As with constant pressure filtration, a large upstream water storage is needed.

3.4.3 Backwashing

Once filter resistance exceeds the available driving force, the accumulated solids must be removed from the filter. In cartridge filters, this process requires dismantling of the filter housing and replacement of the filter cartridges.

Backwashing of deep granular filters involves reversing the flow through the filter at a rate sufficient to expand the filter bed. The deposited material is then dislodged by hydraulic shearing action of the water and abrasion of the grains of filter media. Where cleaning is inadequate, mud balls--masses of filtered solids--develop and, over time, will grow and sink deeper into the filter bed, increasing head loss and decreasing effluent quality. Where backwash rates are inadequate to thoroughly clean the filter, longer duration backwashes must be used (5 to 10 or at an extreme, 15 minutes) to provide the necessary cleaning. Air scour is often used to assist in backwashing.

3.5 SLUDGE STABILIZATION

3.5.1 Introduction

Sludge stablilization processes are key to the reliable operation and performance of any wastewater plant. It is not inappropriate to think of a wastewater plant as a sludge factory. In a sludge stabilization process several factors must be considered, including quantity of sludge to be treated, and ultimate disposal of the sludge.

Sludge stabilization is basically a process to either reduce volatile solids, significantly reduce pathogens, or prepare the sludge for further processing.

3.5.2 Anaerobic Digestion

The purposes of anaerobic digestion are to produce a stabilized sludge, reduce pathogens, reduce sludge quantity by partial destruction of volatile solids, and produce usable gas as a by-product. Anaerobic digestion is the sludge stabilization process utilized at the MacDill AFB WWTP.

3.5.2.1 Basic Theory

Anaerobic digestion is the solubilization and fermentation of complex organic substances by microorganisms in the absence of oxygen. The products of anaerobic digestion are methane, carbon dioxide, trace gases, cells, and stabilized sludge. The microbial population responsible for this conversion process can be divided into three groups, each responsible for a separate function: solubilization, acid formation, and methane formation. Proteins, lipids, cellulose, and other complex organics are solubilized by hydrolysis. These hydrolysis products are then converted to short-chain organic acids including acetic, propionic, and lactic acid. The first two steps together are sometimes referred to as the acid forming stage. These acids are then converted to methane, carbon dioxide, and other trace gases by the methanogens (methane-forming bacteria).

The acid formers and methanogens perform their function and produce acids and methane in sequence. The acid formers are tolerant to environmental changes such as pH and temperature. Their growth rate is relatively fast compared to the methonogens. In contrast, the methanogens are very sensitive to temperature changes, pH and substrate considerations. Their slow growth combined with their intolerance to changing

environmental conditions can result in process upsets. For this reason it is important to continuously monitor the existing conditions in the digester. If methane production is hindered, organic acids accumulate and cause the pH to drop. Once the pH starts dropping, methane production is further curtailed and the ratio of acid produced to methane produced increases. This imbalance may continue until the digester fails and stabilization stops. Anaerobic digesters are designed on the basis of the methanogens' environment limiting the success of the process.

3.5.2.2 Process Description

Generally, anaerobic digesters are classified into two types, low rate and high rate. Low-rate digesters have also been called standard rate or conventional anaerobic digesters. An improvement over the low- or standard-rate system was developed in the 1950s. High-rate systems were characterized by heating, auxiliary mixing, thickening and uniform feeding. An attempt was made to optimize environmental conditions so microorganisms would perform a more complete digestion process.

Heating of the digesting sludge increases the microorganism growth rate along with the digestion rate and gas production. High-rate anaerobic digesters are operated at mesophilic and thermophilic temperature ranges. The mesophilic range is approximately 30° to 38°C and the thermophilic range is 50° to 60°C. Temperature variations have a significant negative effect on the methanogens, causing process upsets. The thermophilic microorganisms are more sensitive to temperature changes than the mesophilic microorganisms.

Many times anaerobically digested sludge does not stratify well and results in a supernatant containing a high concentration of suspended solids that can be detrimental to the liquid wastewater treatment system. Several reasons for poor settling characteristics include incomplete digestion in the digester, which generates gases and causes floating solids and fine-sized solids that have poor settling characteristics. Anaerobic digested sludges thickened above 4 to 4.5 percent total solids generally will not separate in the digester.

The anaerobic digestion process is used to stabilize and reduce the quantity of volatile solids for ultimate disposal. The degree of volatile solids destruction indicates to

the operator whether the digester is functioning properly. A typical anaerobic digester will reduce the volatile solids content of the sludge by 40 to 60 percent. Each digester will display its own peak level of destruction depending on feed sludge characteristics. Various investigations indicate that only 60 to 80 percent of the measured volatile solids fed to the digester are biodegradable, unless industrial wastes or other abnormal characteristics are present.

The percent reduction of volatile solids can be calculated using the formula below:

$$P = \frac{(IN - OUT)}{IN - (IN \times OUT)} \times 100\%$$

Where:
IN = % Volatile Solids in feed sludge (WAS)
OUT = % Volatile Solids in secondary digester
P = % Reduction of volatile solids.

The amount of volatile solids destroyed is a function of both temperature and solids retention time (SRT). In general, increasing the SRT will increase the percent volatile solids destruction. After an optimum SRT is reached additional destruction is minimal. At different temperatures, the total amount of volatile solids destroyed increases for increasing temperatures up to 35°C or the mesophilic range.

The quality and quantity of digester gas produced can be used to evaluate digester performance. Gas production is directly related biochemically to the amount of volatile solids destroyed and is expressed as volume of gas per unit mass of volatile solids destroyed. This specific gas production rate is different for each specific organic substance in the digester. A typical anaerobic digester handling primary and trickling filter sludge should produce approximately 12 to 18 ft^3 of gas per pound of volatile solids destroyed. The amount of gas produced is a function of temperature, SRT, and volatile solids loading.

3.5.2.3 Description of Anaerobic Digestion Facilities

Below is presented a general description of the various components which normally make up an anaerobic digester system.

1. Tank Configuration. Configurations for anaerobic digesters are cylindrical, rectangular, and egg-shaped. Cylindrical is the most common in use. Floors are usually constructed with minimum slope of 1:6 to 1:4 for improved girt removal. Floors may contain one central withdrawal pipe or may be divided into pie-like sections with a separate withdrawal pipe for each section.

2. Tank Covers. Digester designs use covered tanks to collect gas, minimize odors, stabilize internal digester temperatures, and maintain anaerobic conditions. Two types of covers are available, fixed and floating. No digester covers are utilized at the MacDill AFB WWTP at present.

3. Pumps and Piping Configurations. The most commonly used pumps for transporting sludge to and from the anaerobic digester are piston, progressive cavity, and non-clog centrifugals. Piping configurations are designed to promote flexibility for feeding, recirculating, and discharging sludge. Piping is arranged to provide several points for sludge feed and withdrawal, and supernatant withdrawals.

4. Gas Handling Equipment. The necessary pieces of equipment for a typical gas handling system include those for collection, transportation, metering, storage, and safety. Pressure vacuum relief valves are necessary to alleviate positive and negative pressures developed under the digester cover during gas formation. A flame trap is installed between an existing flame source and the digester to prevent the flame from reaching the digester tank. Pressure regulators are used to adjust gas pressures to those needed for various gas utilization systems such as boilers or waste gas burners. Gas meters are used to measure quantity of gas produced, wasted, and used. Waste gas burners are used to eliminate excess gas. The MacDill AFB WWTP digesters are uncovered and as such do not have a gas handling system at present.

5. Mixing Equipment. The most common types of digester mixing equipment are pumped sludge recirculation, gas recirculation and internal mixers. Internal mixing is used in the primary digestion tank at the MacDill AFB WWTP.

6. Heating Equipment. Both internal and external heating equipment have been used to maintain digester operating temperatures. External heat exchangers are the most commonly found. Sludge is pumped through them to attain heat transfer from heated water. No heating equipment is currently in use in the MacDill AFB WWTP digesters.

3.6 SLUDGE DEWATERING

3.6.1 Introduction

Sludge is a major by-product of domestic wastewater treatment. Its disposal is a problem comparable in importance and magnitude to the liquid wastewater treatment problem. Sludge dewatering is an economic necessity to reduce the sludge volume requiring disposal and to retard biological decomposition.

The objective of sludge dewatering is to reduce the capital and operating costs associated with its ultimate disposal by substantially reducing the sludge volume. Dewatering a sludge from 5 percent to 25 percent solids concentration reduces the sludge volume to approximately one-fifth (20 percent) of its original volume.

The sludge dewatering concept is embodied within a category of processes designed to extract water from sludge. In dewatering systems, sufficient water is extracted from the sludge so that it assumes a nonfluid character. No longer a liquid, dewatered sludge is characterized as a damp solid. An arbitrary index used in the wastewater industry to distinguish between dewatered sludge and thickened sludge is a minimum 15 percent solids content for dewatered sludge. It is important to note, however, that the physical characteristics displayed by sludges of a given moisture content will vary, depending on sludge type and conditioning.

Sludge dewatering may be accomplished by a number of natural and mechanical means that incorporate the use of gravity, evaporation, vacuum, centrifugal force, pressure, capillary action, or a combination of any of the above.

Prime considerations in the selection of sludge dewatering methods are cost, availability of disposal site, aesthetic factors, and the environmental impact of the disposal approach on people.

3.6.2 Sludge Drying Beds

Despite a variety of mechanical methods available for sludge dewatering, approximately two-thirds of treatment plants in the United States have sludge-drying beds. By using this procedure, a sludge can be dried to about a 75 percent or less moisture content in a few weeks of dry weather. Such a sludge is conveniently handled

with a shovel or garden fork. The area required for sludge drying beds is primarily determined by climatic conditions.

The dewatering of the sludge on sand beds occurs by filtration of the water through the sand and evaporation of the water from the sludge surface. Filtration is usually accomplished on digested sludge in 1 to 2 days. This is dependent upon the characteristics of the sludge and the depth to which the sludge is placed on the bed. After most of the water is filtered off, the sludge then dries to an equilibrium moisture content with the surrounding air. This final moisture content depends upon the temperature and relative humidity of the air and the nature of the water content. Bound water retained in capillaries and in cell walls will result in a high final moisture content. A high bound-water content is representative of raw or partially digested sludge. Well-digested sludge possesses a low bound-water content and is easily dewatered on sand beds.

Sludge-drying beds normally consist of 4 to 6 inches of sand over 8 to 12 inches of gravel or stone. The bed is drained by tile underdrains placed in the gravel about 6 to 12 feet apart. The spacing of the underdrains depends on the drainage characteristics of the subsoil. The underdrainage may be returned to the head of the plant. The side walls of the beds are made of concrete. The side walls are about 12 inches high and the beds are filled to a depth of 8 to 10 inches. Several smaller beds serve the purpose better than one large bed. The width of the drying bed is so chosen that the vehicle used for removing the dried sludge can be loaded conveniently. Common values for width are about 20 feet. The length is generally held below 100 feet. Sludge may be expected to flow approximately 100 feet from a single outlet when the bed slope away from the outlet is about 0.5 percent.

3.7 LAND APPLICATION OF SLUDGE (BIOSOLIDS)

Land application is the application of biosolids to land to either condition the soil or to fertilize crops or other vegetation grown in the soil. Nearly half of the biosolids production in the United States is currently being used beneficially to improve soils. The types of land that benefit from the application of biosolids include agricultural land, forests, and reclamation sites - collectively called nonpublic contact sites and public parks, plant nurseries, roadsides, golf courses, lawns, and home gardens - collectively called public contact sites.

Biosolids can be either applied to land in bulk or sold or given away in bags or other containers for land application. Biosolids in bulk refers to biosolids that are marketed or given to manufacturers of products that contain biosolids. Biosolids in bags generally refers to biosolids in amounts that are bagged and generally marketed for use on smaller units of land such as lawns and home gardens.

Biosolids are generally land applied using one of several techniques. The biosolids may be sprayed or spread on the soil surface and left on the surface (e.g., on pastures, range and forest land, or lawn). They also may be incorporated into the soil after being surface applied or injected directly below the surface for producing row crops or other vegetation and for establishing lawns.

Biosolids in a liquid state can be applied using tractors, tank wagons, irrigation systems, or special application vehicles. Dewatered biosolids are typically applied to land using equipment similar to that used for applying limestone, animal manures, or commercial fertilizers. Both liquid and dewatered biosolids are applied to land with or without subsequent incorporation into the soil.

Because biosolids are typically treated before being land applied, their use poses a low degree of risk. Biosolids from the MacDill AFB WWTP are transported as liquid to land farms in Charollette and DeSoto Counties for surface spreading as specified in the facilities permit.

3.8 DISINFECTION

3.8.1 Introduction

From the viewpoint of health, the disinfection process is a very important consideration. It is the unit process that provides a barrier to the transmission of waterborne disease by destruction of pathogens before release of the waste stream to the environment. Disinfection of wastewater effluents has contributed to the dramatic reduction that has occurred through the years in the incidence of waterborne disease outbreaks. Disinfection refers to the selective destruction of disease-causing organisms. All of the organisms are not destroyed in the process. This differentiates disinfection from sterilization, which is the destruction of all organisms.

3.8.2 Liquid-Gas Chlorine

Chlorine is one of the chemical elements. Commercial chlorine is a liquified gas under pressure. As a liquid, it has a clear, amber color. In a gaseous form, it has a greenish-yellow color and a strong pungent odor. Chlorine is fed as a gas from 150-pound bottles at the MacDill AFB WWTP. Liquid chlorine is about one and one half times as heavy as water, and as a gas it is heavier than air. Chlorine is neither explosive nor flammable; however, it will support combustion. At atmospheric pressure, liquid chlorine boils at about -30°F and freezes at about -150°F. One volume of liquid chlorine, when vaporized, will yield about 460 volumes of gas. When exposed to normal atmospheric pressure and temperature, liquid chlorine will vaporize to a gas.

Chlorine has a very strong affinity for many substances and will react with almost all the elements and with many inorganic and organic compounds, usually with the evolution of heat. At elevated temperatures, it reacts vigorously with most metals. In a moisture-free state at ordinary temperatures, it is relatively non-corrosive. However, in the presence of moisture, it is highly corrosive.

Several reactions will occur simultaneously when chlorine is added to clear wastewater. The reactions are affected by temperature, pH, buffering capacity of the wastewater, and the nature of the chlorinating agent.

When chlorine is added to water the chemical reaction is:

$$Cl_2 + H_2O = HOCL + HCl$$

$$HOCl = H^+ + OCl^-$$

At pH values below 7.5, the hypochlorous acid (HOCl) is the predominant compound, while at pH values above 7.5, the hypochlorite ion (OCl-) predominates. Hypochlorous acid is the more effective disinfection agent. The HOCl and OCl- available after all reactions have been completed are defined as free chlorine residual.

Wastewater contains many complex substances which will react directly with chlorine. Any ammonia available will react with the HOCl to form chloramines. Chloramines are also disinfecting agents, although not as effective as free chlorine. The chloramine residual is called combined residual.

Before the chlorine and the chloramines can destroy the bacteria, all other direct chemical reactions must be satisfied. The chlorine demand of the wastewater is the amount of chlorine needed to satisfy direct chemical reactions and to produce a minimum residual of chlorine or chloramine.

3.8.2.1 Mixing

It is imperative that the chlorine solution and wastewater be mixed as instantaneously and completely as is mechanically possible. This rapid mixing is termed flash mixing and is necessary to assure that chlorine is available to react simultaneously with every chemically active soluble and particulate component of the wastewater.

In the design of the chlorination system, it is important to provide conditions that will limit the release of chlorine or chlorine compounds from solution. This is necessary from an efficiency standpoint and to prevent a health hazard from chlorine gas in the atmosphere. The most essential conditions are (1) that the chlorine distributor should be submerged at least 2 feet below the wastewater level when chlorine water solution is applied and from 5 to 10 feet, depending on amount fed, when chlorine gas is applied with effective diffusion, and (2) that the wastewater flow following the application and adequate mixing of chlorine should not be subjected to excessive turbulence.

3.8.2.2 Contact Time

Once chlorine is completely mixed with wastewater, plug flow through the contacting system must be maintained. The more closely a contactor design approaches 100 percent plug flow, the better the performance should be.

Plug flow contacting can be effectively accomplished by proper utilization of outfall lines that should always flow full. Successful contacting can also be provided in open channels, although the rectangular and other compact designs provide more economical use of land in most locations. All contactors should be designed with flow gradients that minimize settling of solids. although some solids accumulation is unavoidable. Solids and any slime accumulations on fluid contact surfaces must be removed at regular intervals. Carelessness in this regard can lead to increased chlorine demand and erratic bacterial quality in the disinfected effluent.

Assuming 95 percent plug flow, a minimum contact time of 30 minutes at maximum design flow is a good guideline for general use. A nominal increase in contact time (under the flow conditions specified) may be advantageous in some situations, but a reduction in the contact time will reduce the margin of safety unless an offsetting increased chlorine concentration is provided.

3.8.2.3 Dosage and Residual Control

Successful disinfection with chlorine is extremely dependent on providing rapid response to fluctuating chlorine demand to maintain the chlorine residual at a predetermined desirable level.

Effective disinfection thus requires that there be a defined chlorine residual after a suitable contact period. Because the waste of each community requires a special determination of the dosage that will yield the desired or required chlorine residual, efficient and economical operation demands that the application rate be regulated as often as necessary to insure efficient and economical operation. Only by frequent determinations of chlorine residual can the dosage rate, and thus the effectiveness of disinfection, be satisfactorily controlled. Satisfactory disinfection of reuse water is obtained when the chlorine residuals after 15 to 30 minutes contact are above 1.0 mg/l. A minimum chlorine residual of 1.0 mg/l is required at the MacDill AFB WWTP.

Chlorine residual is the critical factor in disinfection. The chlorine applied must persist long enough to attain the desired coliform reduction. Others factors which are involved in the chlorine disinfection process include pH, temperature, concentration of organisms, and the nature and size of particulate material present.

3.9 ADDITIONAL REFERENCES

To enhance the operator's knowledge of the treatment processes at the MacDill AFB wastewater plant, a number of additional references are available. These include:

- Sacramento Course--*Operation of Wastewater Treatment Plants*, Volumes 1 & 2
- Sacramento Course--*Industrial Waste Treatment*
- Air Force Manual AFM 91-32--*Operation and Maintenance of Domestic and Industrial Wastewater Systems*
- *Standard Methods for the Examination of Water and Wastewater,* 18th Edition
- *Manual of Practice OM-9--Operation and Maintenance of Activated Sludge Plants*
- *Manual of Practice 7--Operation and Maintenance of Wastewater Collection Systems*
- *Manual of Practice OM-3--Plant Maintenance Program*
- *Manual of Practice 11--Operation of Wastewater Treatment Plants*
- *Manual of Practice OM-1--Wastewater Sampling for Process and Quality Control*

All of the above manuals of practice (MOP) are available from the Water Environment Federation.

CHAPTER 4
SAMPLING AND ANALYTICAL SCHEDULE

CHAPTER 4
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4.1 INTRODUCTION

The purpose of the analyses performed in the MacDill AFB WWTP laboratory is to provide data to be used in decision making and fulfill reuse permit requirements. By relating lab results to the waste treatment operation, the operator can effectively make process decisions, determine the efficiency of the treatment process, identify trends in the process, and determine the causes of plant upsets.

The value of any laboratory result depends on the integrity of the sample. Too often, the sole burden for providing accurate laboratory results rests on the analyst running the sample. However, the method used in obtaining the sample is just as important to the analyst as the analytical procedures he or she follows.

Obtaining a sample for laboratory analysis is based on the assumption that the sample obtained is a part of the whole being measured. This idea is most important because if the sample is not truly representative, all subsequent conclusions, decisions, and actions will be affected by the errors in the sample. Samples must be collected so that nothing is added or lost and that no changes occur during the time between collection and laboratory examination of the sample. Since the design and successful operation of any wastewater treatment plant are dependent upon the results of laboratory analysis, sampling is one of the most critical steps and the one typically introducing the greatest errors in these results. Permit required samples and other recommended process control samples for the MacDill AFB wastewater plant are presented in Table 4.1. The laboratory location where analyses are to be performed is also presented in Table 4.1.

The validity of the laboratory analysis will depend upon attention to the following details:

1. Be sure that the sample and sampling point will be truly representative of the wastewater.
2. Use proper and acceptable sampling techniques and sampling containers.

TABLE 4.1

**MacDILL AFB WASTEWATER TREATMENT PLANT
RECOMMENDED SAMPLING/ANALYTICAL SCHEDULE**

Parameter	Frequency	Laboratory	Permit Requirement
Influent CBOD	biweekly	WWTP and Contract	Yes
Final Effluent CBOD	1/week	WWTP and Contract	Yes
Influent TSS	biweekly	WWTP and Contract	Yes
Aeration Basin MLSS	Daily	WWTP	
Return Sludge MVSS	Daily	WWTP	
Secondary Clarifier Effluent TSS	Daily	WWTP	
Final Effluent TSS	Daily	WWTP and Contract	Yes
Influent Settleable Solids	Daily	WWTP	
Aeration Basins Settleable Solids (30 min.)	Daily	WWTP	
Return Sludge Settleable Solids (30 min.)	Daily	WWTP	
Final Effluent Settleable Solids	Daily	WWTP	
Filter Dissolved Oxygen (D.O.)	2/week	WWTP	
Final Effluent D.O.	Daily	WWTP	
Aeration Basin D.O.	4/week	WWTP	
Influent pH	Daily	WWTP	
Effluent pH	Continuous	WWTP	Yes
Effluent Chlorine Residual	Continuous	WWTP	Yes
Effluent Nitrate-Nitrogen	1/week	Contract	Yes
Effluent Turbidity	Continuous	WWTP	Yes
Digester Total Solids	1/week	WWTP	
Digester Volatile Solids	1/week	WWTP	
Waste Sludge Total Solids	1/week	WWTP	
Waste Sludge Volatile Solids	1/week	WWTP	
Digested Sludge Nutrients	1/month	Contract	
Digested Sludge Metals	1/month	Contract	
Influent Oil and Grease	2/month	Armstrong Lab	
Influent Oil and Grease	2/month	Armstrong Lab	
Influent COD	1/month	Armstrong Lab	
Effluent COD	1/month	Armstrong Lab	
Influent TKN	1/month	Armstrong Lab	
Effluent TKN	1/month	Armstrong Lab	
Influent Nitrate	1/month	Armstrong Lab	
Influent Orthophosphate	1/month	Armstrong Lab	
Effluent Orthophosphate	1/month	Armstrong Lab	
Influent Sulfate	1/month	Armstrong Lab	
Effluent Sulfate	1/month	Armstrong Lab	
Effluent Fecal Coliform Bacteria	Daily	Contract	Yes

3. Be sure that proper sample preservation techniques are followed until the samples are analyzed.

4. Ensure that the sample is collected at the correct location and that it is the proper type of sample (composite, flow proportioned composite, grab).

4.2 SAMPLING TECHNIQUES AND CONSIDERATIONS

Because of the lack of uniformity of wastewater, attention to the following basic principles will aid in obtaining a proper sample:

1. Sampling points must be selected carefully to assure good mixing of the material to be sampled. Samples should be collected from the main body of flow where the velocity is high and will not be influenced by previous deposits or interfering side currents.

2. Sampling points should be well marked so that all samples are taken from the same place. In addition, proper sampling equipment should be available, and adequate safety precautions must be observed.

3. Sampling containers should be rinsed two or three times with the water to be collected before sample collection except when biological samples are to be collected or when the sample bottle contains a chemical preservative.

4. Sample lines should be well flushed before sample collection to ensure that the sample is representative of the supply source. If, for example, a sample line will hold a volume of 3 gallons from supply source to sample tap, then a minimum of 5 gallons of wastewater should be drained from the line before the sample is obtained.

5. Appropriate container for the type of analysis to be run should be used (see Table 4.2).

6. Proper sample preservation techniques should be used (see Table 4.2).

7. Adequate volume of sample must be obtained. Samples should be large enough for the required analysis plus an additional amount for a second confirmation analysis in case of doubtful results (see Table 4.2).

8. Sample containers should be labeled as to date, time, exact sample point, type of sample (grab or composite), sample collector, preservatives, if any, and any other information that might have influence on the methods of analysis, results, or interpretation of those results.

9. Composite sample reservoirs should be well-mixed before samples are obtained from them, and all samples should be mixed again before analysis.

10. The appropriate sample type (grab or composite) must be obtained depending on the type of analysis to be run. Reference Table 4.4.

11. Samples should be analyzed as soon after collection as possible for greatest reliability. Some tests must be run on site because the sample composition will change before the sample reaches the lab.

12. Sampling times for grab samples should be selected to represent typical weekday averages or varied from day to day to represent a cross-section of the waste characteristics. Remember, a sample taken early Monday morning may, in actuality, be a sample of the waste from Sunday night.

13. Where necessary to avoid an excess of floating material, the mouth of the collecting container should be held a few inches below the surface level.

4.2.1 Grab Samples

Grab samples are representative of the characteristics of the wastewater at the instant the sample is caught. When it is only possible to collect grab samples, it is preferable that they be collected when the treatment plant is operating at peak flow or organic load conditions. Grab sampling times may be staggered to account for the hydraulic detention time of each unit. If the hydraulic detention time of a process unit is 2 hours, the grab sample of the effluent may be collected 2 hours after the influent sample, thus the samples can be assumed to be representative of the wastewater before and after treatment.

In addition, a grab sample may be taken for any of the following reasons:

1. The waste stream to be measured does not flow on a continuous basis.
2. A "slug" or batch discharge or other unusual or undesirable situation is observed.
3. A condition or operation is of short duration and quite uniform.
4. The waste characteristics are relatively constant over extended periods of time.
5. To determine if a composite sample is averaging out extreme changes in a parameter (i.e., pH) that can be detrimental to the treatment process.
6. Permit requirements dictate grab samples for analyses of selected parameters.

4.2.2 Composite Samples

A composite sample results from the combination of multiple grab samples on a time or flow proportionate basis over a set time period. The composite sample is useful for analysis of wastewater constituents that do not deteriorate or change over extended time periods with proper preservation and where the average composition of the wastewater is sought. Composite samples provide useful data if the fluctuations in wastewater characteristics are not extreme and tend to minimize the effect of intermittent changes in wastewater characteristics and flow. Currently, samples are manually collected and composited according to flow at the MacDill WWTP. Samples are collected every two hours during periods when the WWTP is staffed.

The best type of composite sample is one in which the volume of each grab sample is in direct proportion to the flow reading at that instant. The following example illustrates the sample volumes to be collected on a 12-hour composite:

Time	Flow (MGD)	Factor	Sample Volume (ml)	Time	Flow (MGD)	Factor	Sample Volume (ml)
6am	0.2	100	20	12N	1.4	100	140
7am	0.3	100	30	1pm	1.6	100	160
8am	0.6	100	60	2pm	1.5	100	150
9am	0.9	100	90	3pm	1.3	100	130
10am	1.2	100	120	4pm	1.3	100	130
11am	1.2	100	120	5pm	1.2	100	120

The total volume of samples collected in the above example of a 12-hour composite would have been 1270 ml. If a composite is made from individually collected grab samples, then each of the individual grab samples should be shaken vigorously to provide a uniform mixture before the samples are pooled together. The pooled composite sample should also be thoroughly mixed immediately prior to obtaining a sample for analysis. Failure to do so may contribute to serious errors.

The amount to be collected during a specific sampling period can be calculated using the following formula:

$$\text{Amount of sample to collect} = \frac{\text{(Rate of flow, MGD, at time of sampling)(Total sample required, ml)}}{\text{(Number of samples collected)(Average daily flow, MGD)}}$$

Example Calculation:

			Data:
1.	Rate of flow at sample time	=	2 MGD
2.	Total sample required, ml	=	4000 ml
3.	Number of samples to collect	=	24
4.	Average daily flow	=	1.5 MGD
	Amount of sample to collect	=	(2MGD) (4000ml) / 24) (1.5 MGD)
		=	222.2 ml

4.2.3 Automatic Samplers

Automatic samplers are used to collect a series of grab samples on a constant time-constant volume principle or on a flow proportionate basis. The flow proportionate automatic samplers function by collecting a definite volume of sample each time a predetermined number of gallons of wastewater has passed the flow measuring device. This is the approach to flow compositing at the MacDill AFB WWTP.

In selecting automatic samplers and sampler locations, consideration should be given to the following:

1. Resistance of the sampler to the particular types of wastes being treated (i.e., wastes highly acidic or containing organic solvents).
2. Protection of the sampler from corrosive atmospheres, particularly in confined areas containing raw wastes.
3. That the sampler provide sufficient flow velocity in the intake tube to prevent settling of heavier solids particles.
4. That adequate sample-preservation is provided, either refrigeration or ice packs.
5. That sampler placement does not exceed the suction head capabilities of the sampler.
6. That compatible interfacing of the flow meter and sampler is possible.
7. That adequate safety is afforded personnel during recovery of the composite sample.

8. That a purge cycle is available to clean the intake line before and after each sample is collected.

As with all pieces of equipment, preventive maintenance and cleaning schedules should be followed. In particular, the intake tubes should be cleaned regularly to prevent solids buildup and periodic slough-off that can contaminate samples.

4.3 OTHER SAMPLING CONSIDERATIONS

4.3.1 Sample Preservation

Complete preservation of any sample, regardless of source, is almost impossible and can never be achieved for every constituent in the sample. Preservation techniques can only, at best, retard the biological and chemical changes that inevitably continue after the sample is removed from the source. The methods of preservation are limited and are intended generally to (1) retard biological action, (2) retard hydrolysis of chemical compounds and complexes, and (3) reduce volatility of constituents. Preservation methods are generally limited to pH control, chemical addition, refrigeration, and freezing.

Table 4.2 shows the various preservatives that may be used to retard changes in samples. Table 4.2 gives types of containers, preferred method of preservation, and holding times for various test parameters.

4.3.2 Cleaning Sample Bottles

A common mistake made by those sampling is to use a bottle that has held "unknown" materials as a sample container. Often these containers have held oily or greasy substances which cling to the walls of the bottle and resist rinsing. Only new bottles or bottles that have been cleaned by acceptable methods in the laboratory should be used as sample bottles. It is good practice to designate bottles to be used exclusively to hold particular samples. These containers should be carefully labeled and used for no other purpose. These containers should be thoroughly rinsed before and after each use and periodically cleaned in the laboratory using only authorized laboratory cleaners.

4.3.3 Sample Volumes

Adequate volumes must be obtained to perform the desired analysis. The volume collected should be large enough to repeat the procedure if necessary. Never "dump" the remainder of a sample until your results are completed and considered to be satisfactory.

TABLE 4.2
RECOMMENDED SAMPLING SIZES AND PRESERVATION METHODS

Determination	Container*	Minimum Sample Size mL	Preservation	Maximum Storage Recommended/Regulatory
Alkalinity	P, G	200	Refrigerate	24 h/14 d
Ammonia Nitrogen	P, G	500	H_2SO_4, Refrigerate	28 d/28 d
BOD	P, G	1000	Refrigerate H_2SO_4 to pH <2	6 h/48 h
Chlorine, residual	P, G	500	Analyze immediately	Analyze immediately
COD	P, G	250	H_2SO_4, Refrigerate	28 d/28 d
Fecal Coliform Bacteria	P, G	100	Refrigerate	6 h/6 h
Metals, general	P(A), G(A)	--	For dissolved metals filter immediately, add HNO_3 to pH <2	6 months/6 months
Chromium VI	P(A), G(A)	300	Refrigerate	24 h/48 h
Nitrogen, Total	P, G	1,000	H_2SO_4, Refrigerate	28 d/ 28 d
Nitrates	P. G.	100	Refrigerate	48 h/48 h
Nitrites	P, G	100	Refrigerate	48 h/48 h
Oil and Grease	G, wide-mouth calibrated	1000	Add H_2SO_4 to pH <2, refrigerate	28 d/28 d
Oxygen, dissolved:	G, BOD bottle	300		
Electrode			Analyze immediately	Analyze immediately
Winkler			Titration may be delayed after acidification	8 h/8 h
pH	P, G	100	Analyze immediately	Analyze immediately
Phosphorus, Ortho	P. G.	100	Filter	48 h/48 h
Phosphorus, Total	P. G.	100	H_2SO_4, Refrigerate	28 d/28 d
Solids	P, G	100	Refrigerate	7 d/7-14 d
Temperature	P, G	1,000	Analyze immediately	Analyze immediately

* See text for additional details. For determinations not listed, use glass or plastic containers; preferably refrigerate during storage and analyze as soon as possible. Refrigerate = storage at 4°C, in the dark. P = plastic (polyethylene or equivalent); G= glass; G(A) or P(A) = rinsed with 1+1 HNO_3; G(B) = glass, borosilicate; G(S) = glass, rinsed with organic solvents.

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4.4 SAMPLING POINTS AND ANALYTICAL SCHEDULE

Table 4.3 presents the suggested sampling points at the MacDill AFB WWTP. These points should be used consistently by all operators to help ensure the uniformity of all samples. Any change in sampling points or addition of sampling points must be communicated to all operators.

Table 4.4 presents a suggested sampling schedule for analyses run at the WWTP laboratory. This schedule can be adjusted as plant conditions dictate.

TABLE 4.3
MacDILL AFB WASTEWATER TREATMENT PLANT
SUGGESTED SAMPLING POINTS

Sample Type	Sample Point
Plant Influent	At plant headworks between grit chamber and Parshall flume
Plant Effluent (for Turbidity)	At rectangular weir in filter effluent chamber
Plant Effluent	At effluent from chlorine contact chamber
Aeration Tanks	Below the surface within aeration basins
Return Activated Sludge	Discharge of RAS Telescopic values
Secondary Clarifiers	In collection troughs of clarifiers
Anaerobic Digester	From bottom of tanks

TABLE 4.4
RECOMMENDED ANALYTICAL SCHEDULE

Sample	MON	TUES	WED	THUR	FRI	SAT	SUN
Influent BOD	--	C	--	--	C	--	--
Final Effluent BOD	--	C	--	--	C	--	--
Influent TSS	C	--	C	--	--	--	--
Secondary Clarifier TSS	C	C	C	C	C	C	C
Digester Supernatant TSS	G	--	G	--	G	--	--
Aeration MLSS	G	G	G	G	G	G	G
Aeration MLVSS	G	G	G	G	G	G	G
Return Sludge TSS	G	G	G	G	G	G	G
Return Sludge VSS	G	G	G	G	G	G	G
Final Effluent TSS	G	G	G	G	G	G	G
Influent Settleable Solids	G	G	G	G	G	G	G
Aeration Settleable Solids	G	G	G	G	G	G	G
RAS Settleable Solids	G	G	G	G	G	G	G
Effluent Settleable Solids	G	G	G	G	G	G	G
Filter Effluent DO	G	G	G	G	G	G	G
Aeration DO	G	G	G	G	G	G	G
Effluent DO	G	G	G	G	G	G	G
Influent pH	G	G	G	G	G	G	G
Effluent pH	I	I	I	I	I	I	I
Digester Total Solids	G	--	--	--	--	G	--
Digester Volatile Solids	G	--	--	--	--	G	--
Waste Sludge TSS	G	G	G	G	G	G	G
Waste Sludge VSS	G	G	G	G	G	G	G
Influent Temperature	G	G	G	G	G	G	G
Effluent Temperature	G	G	G	G	G	G	G
Effluent Chlorine Residual	I	I	I	I	I	I	I
Effluent Fecal Coliform	G	G	G	G	G	G	G
Tertiary Filter Effluent Turbidity	I	I	I	I	I	I	I

NOTE:
1. Sample Type: C = Composite, G = Grab, I= Continuous and Grab

CHAPTER 5
LABORATORY TESTING

CHAPTER 5
LABORATORY TESTING

5.1 INTRODUCTION

Analytical testing conducted for the MacDill AFB WWTP for permit requirements will generally be conducted by an outside contract laboratory for most parameters. Some parameters, such as pH, turbidity and Total Residual Chlorine, will be done at the WWTP by continuous on-line analyzers. The Florida Department of Environmental Control has in place a strict laboratory certification program that incorporates criteria for labs and the analyst in the attainment of state certification. The certification is applicable only if a designated person is performing the required tests at a specific laboratory. Because available laboratory staffing at MacDill AFB is limited, it is imperative that the services of an outside certified lab be utilized for permit required analyses.

However, it is necessary for all operators to have a general knowledge concerning the analytical procedures used at the plant. Such knowledge will allow the operators to evaluate the laboratory data and make determinations as to the validity of the data and will provide the operators with a better understanding of the data collected and allow them to make more effective use of this data. By relating meaningful lab results to daily operation, the operator can effectively make process decisions, determine the efficiency of the process, predict and prevent problems that are developing, and determine causes of plant upsets.

The standard text used by most wastewater labs is entitled *Standard Methods for the Examination of Water and Wastewater*. This text must be followed explicitly for results to be acceptable to regulatory agencies. Some operators find it difficult to understand and to follow *Standard Methods*. This chapter is not to be considered as a substitute to *Standard Methods* but as a simplified guide for use by the MacDill AFB operations staff. As operators master these techniques, they should refer to *Standard Methods* to become aware of the possible pitfalls and interferences associated with these methods. This

chapter deals primarily with the laboratory analyses to be performed at the MacDill AFB wastewater treatment plant laboratory.

Other references to be consulted by the treatment plant operators for information concerning laboratory analyses include:

- *Methods for Chemical Analysis of Water and Wastes*, EPA.
- *Simplified Laboratory Procedures for Wastewater Examination*, Water Pollution Control Federation Publication No. 18.
- *Operation of Wastewater Treatment Plants*, Volume II, Sacramento State University.
- *Hach Handbook of Water Analysis*, Hach Chemical Company, 1979.

5.2 BIOCHEMICAL OXYGEN DEMAND ANALYSIS

5.2.1 Scope and Application

5.2.1.1 This method is applicable to the measurement of biochemical oxygen demand (BOD) in drinking, surface and saline waters, domestic and industrial wastes.

5.2.1.2 Concentrations of BOD from 2 up to about 8 mg/l may be measured directly. Multiplication by applicable dilution factors extends the range.

5.2.1.3 The effluent BOD from the MacDill AFB WWTP is limited by the reclaimed water permit. The permit requires a specified frequency of analysis for BOD.

5.2.2 Methodology

5.2.2.1 Specific Method Utilized

This method was developed as a sequential, step-by-step procedure and is derived directly from Method 5210-B, p. 5-2 of *Standard Methods For The Examination of Water and Wastewater*, 18th Edition; 1992.

5.2.2.2 Summary of Method

The method consists of filling with sample, to overflowing, an airtight bottle and incubating it at constant temperature for 5 days. Dissolved oxygen is measured initially and after incubation, and the BOD is computed from the difference between initial and final DO.

5.2.3 Sample Pretreatment

5.2.3.1 Temperature Adjustments

1. Cold samples must be warmed slowly to room temperature, 20.0 ± 1.0°C, before making dilutions.
2. Warm samples must be cooled slowly to room temperature, 20.0 ± 1.0°C, before making dilutions.

5.2.3.2 Check for $C1_2$ Residual

1. Effluent samples must be free of chlorine residual.

2. Check the effluent samples for Cl_2 residual using the Hach DR100 Colorimeter instrument. Use other operating and quality assurance procedures that are provided in the Instrument Calibration Logs/Instructions book to calibrate and operate the DR100.

5.2.3.3 Adjustment of Sample pH

1. Sample pHs must be within the 6.5 - 7.5 range for the BOD test.

2. Analyze the samples on the pH meter. Those samples having a low pH (acidic) must be adjusted to the aforementioned pH range using sodium hydroxide solution. Those samples having a high pH (alkaline) must be adjusted to the same range using sulfuric acid solution. The solutions must be of such strength that the sample is not diluted by more than 0.5 percent.

3. Calibrate the pH meter using the Instrument Calibration Logs/Instructions book. Refer to this book for instructions on how to perform a pH test.

4. Raise or lower the pH of the samples by the dropwise addition of sodium hydroxide or sulfuric acid solutions while the sample is stirring and being monitored by the pH meter and probe.

5.2.4 Sample Dechlorination

5.2.4.1 Determination of the Amount of Sodium Sulfite Solution Needed to Dechlorinate Samples

1. Measure 100 ml of chlorinated sample in a 100-ml graduated cylinder and pour it into a 500-ml Erlenmeyer flask. (This procedure only need be performed if the effluent samples contain Cl_2 residual.)

2. Using a 10-ml serological pipette, measure 10 ml of 1 + 50 sulfuric acid solution. Transfer into the Erlenmeyer flask and swirl to mix.

3. Using a 10-ml serological pipette, measure 10 ml of 10% potassium iodide solution. Transfer into the Erlenmeyer flask and swirl to mix. The solution will turn a red-brown color.

4. Fill a 25-ml buret with 0.025N sodium sulfite solution. Bleed the air out of the stopcock and refill to the 0.0 ml line.

5. Place the Erlenmeyer flask on a magnetic stir plate, add a magnetic stir bar, and titrate the sodium sulfite at a fast dropwise rate while stirring. When the red-brown color changes to one of a pale yellow, stop the addition of sodium sulfite solution.

6. Squirt approximately 2 ml of starch indicator solution into the flask. The color of the contents should turn to a pale or medium blue color.

7. Continue the addition of sodium sulfite from the buret at a dropwise rate of about 1 drop/second.

8. When the solution turns from blue to colorless, immediately stop the addition of sodium sulfite.

9. Record the ml of sodium sulfite used to one place to the right of the decimal point.

10. Discard the 100-ml sample in the Erlenmeyer flask.

11. Calculate the amount of 0.025N sodium sulfite needed to dechlorinate the entire BOD sample by following the example calculation below.

    EXAMPLE CALCULATION:

    3.2 ml of 0.025N sodium sulfite was used in the titration of the 100 ml sample and the entire BOD sample volume is 1 liter (1000 ml).

$$\frac{1000 \text{ ml (ml of entire comp.)}}{100 \text{ ml (amt. used for titration)}} \times \frac{3.2 \text{ ml (ml of } 0.025\text{N } Na_2SO_3)}{1} = 32 \text{ ml}$$

    32 ml of Na_2SO_3 is needed to dechlorinate the remaining or entire BOD composite sample.

12. Using a serological pipette, or a graduated cylinder if the amount calculated is greater than 10 ml, transfer the calculated amount of Na_2SO_3 to the BOD composite sample, and shake to mix the contents.

13. The sample must stand for 20 minutes to allow for the dechlorinating action of the Na_2SO_3.

14. Repeat Steps 1-3 to ensure the dechlorination has taken place. The solution color should be colorless if all Cl_2 has been removed. If the solution is pale blue, there is still Cl_2 present and Step 15 should be performed.

15. Add 2 drops of the 0.025N Na_2SO_3 and mix if the solution changes to a pale blue. Proceed to step 16.

16. Repeat Steps 1-3 and 15 until the solution remains colorless, then discard the titration sample.

5.2.5 Laboratory Pure Water

5.2.5.1 Distilled Water Preparation

1. Distill 3-6 liters of water (quantity used in the BOD test depends upon the number of BOD bottles that will be set up. Check pH, Cl_2 residual, and megohms upon cooling. pH should be 5.5-7.5, conductivity should be greater than 0.2 megohm as resistivity or less than 5.0 micromhos/cm at 25° C, and free chlorine should be 0.0.

2. Store the water in a large, small-necked jug with a dispensing spout on the bottom. Plug the jug with a piece of loose fitting cotton.

3. Place the water-filled jug in the BOD incubator at 20°C for 24 hours prior to the BOD test.

4. Store another portion of distilled water in a smaller, small-necked jug. Plug the jug with a piece of loose-fitting cotton. This will be used for a seed solution.

5. Store the seed water jug in the BOD incubator at 20°C for 24 hours prior to the BOD test.

5.2.5.2 BOD Dilution Water

1. Remove the large jug containing distilled water just before the BOD dilutions are ready to be made.

2. Empty the contents of one of the Hach BOD Nutrient Buffer Pillows (for preparation of either 3 or 6 liters -- which one depends upon the volume of the distilled water in the jug and/or the amount of the volume of dilution water required to fulfill all the dilution amounts of the BOD bottles that

will be set up) into the large jug, stopper the jug, and shake vigorously for 1 minute to dissolve and mix the contents of the pillow into the water.

5.2.6 Polyseed Innoculum -- Seed

5.2.6.1 Needed Items

1. Small jug of aerated distilled water at 20°C.
2. One Polyseed capsule.
3. Two Hach, BOD Nutrient Buffer Pillows for Preparation of 300 ml.
4. 500 ml graduated cylinder.
5. 1000 ml beaker.
6. Magnetic stir plate and bar.

5.2.6.2 Procedure

1. Measure 600 ml of the aerated distilled water using the 500-ml graduated cylinder and pour it into the 1000-ml beaker.
2. Add the contents of the BOD Nutrient Buffer Pillows to the water in the beaker.
3. Mix the buffer solution using the magnetic stir bar and the magnetic stir plate.
4. Pour off 100 ml of the nutrient buffer solution and discard it. (This solution may be saved if it will be needed to dilute a very strong sample such as an influent.)
5. Open a BOD Polyseed capsule and empty the contents into the beaker of nutrient buffer solution. (Be vary careful not to inhale dust from the Polyseed capsule--it will cause serious respiratory problems. Wash hands after handling.)
6. Place the seed solution on the magnetic stir plate and stir. This seed solution must be stirred throughout the entire BOD set up procedure to keep the bacteria in suspension. The seed solution cannot be used for 1 hour prior to its addition to the BOD bottles. It should not be used after 6 hours from the time its prepared.

5.2.7 BOD Procedure

5.2.7.1 Needed Items

1. BOD bottles in their racks.
2. Pipettes, assorted volumes and types.
3. Graduated cylinders, assorted volumes.
4. Shallow pan (for catching probe rinse water).
5. Wash bottle filled with distilled water.
6. DO probe, meter, and their calibration instructions.
7. BOD bench sheet (filled out beforehand containing: % dilutions of specific samples, ml seed used, seed controls, standard solutions, laboratory ID numbers, dates, times, and analysts initials.) An example bench sheet is included in Appendix A.

5.2.7.2 Set Up

1. Calibrate the DO meter probe to give it 15 minutes warm-up time. See Section 5.2.9.
2. Fill the three bottles reserved for dilution water blanks all the way with dilution water from the large dispenser jug.
3. Fill all other bottles full enough to allow some space for other solutions that will need to be added such as: seed control solution, influent and effluent samples, standard solutions, and seed for the samples that require it.
4. Add the required ml of samples and standards to produce the desired concentrations. (To find the ml of sample needed to produce a 20% dilution, multiply 20 by 3 (it's a 300-ml bottle) and you will get 60. The amount of effluent sample needed for that bottle is 60 ml.)
5. To prepare a 2% glucose-glutamic acid standard solution, obtain one Hach Glucose-glutamic Acid BOD Standard Solution Voluette. Shake the voluette vigorously, snap off the neck, and promptly remove 3.0 ml using a volumetric pipette. Transfer the solution to a bottle filled 3/4 full with dilution water.

6. Swirl the contents of the voluette and remove another portion using the 3.0-ml volumetric pipette. Transfer the solution to another bottle filled 3/4 full with dilution water.

7. Repeat Step 6 for the remaining bottle.

   NOTE This standard is a check to ensure the activeness of the seed used and the purity of the distilled water. A standard check should be performed for approximately every tenth sample run. If the 5-day BOD value of the standard check solution is outside of a 200±37 mg/l range, reject any BOD results made with the seed and dilution water, and find the cause of the problem.

8. Using a 50-ml graduated cylinder, measure the appropriate amount of seed solution required for each of the three seed control bottles, and pour into the respective bottles. The amount of seed solution used in the control bottles depends on the calculated seed correction factor. The calculated seed correction factor must be within a range of 0.6-1.0 mg/l; therefore, the amount (ml) of seed control solution used must produce a calculated seed correction within this range.

9. Using a wide-tipped, 10-ml serological pipette, transfer 4.0 ml of seed solution to each of the bottles that need seed. Examples of samples needing seed are: untreated industrial wastes, disinfected wastes, high temperature wastes, or wastes that have extremely high pH values.

10. Finish the last part of the DO meter calibration.

    NOTE This next part of the BOD procedures has to be completed within 15 minutes from the time you add seed to the samples, because the microbial activity will quickly deplete the O_2 in the bottles and a true initial DO will not be obtained.

5.2.7.3 Initial DO Readings

1. Insert the stirring boot of the DO electrode into the first blank dilution water bottle. Slip the DO electrode into the stirring boot. Place on the magnetic stirrer and stir. Wait for the meter to stabilize and record the DO concentration (in mg/l) in the space provided on the BOD bench sheet.

2. Stopper, water seal, and cap the bottle.

3. Record the DO that was obtained for the first bottle of blank dilution water for the remaining two bottles of blank dilution water. Stopper, water seal, and cap the bottles as soon as the DO determinations are completed.

4. Read and record the DO for each of the remaining sample bottles using the same method as stated in Step 1 above.

5. If nitrification inhibition is desired add 3 mg 2-chloro-6-(trichloro methyl) pyridine (TCMP) to each 300-mL bottle before capping or add sufficient amounts to the dilution water to make a final concentration of 10 mg/L.

6. Stopper, water seal, and cap the bottles as you find the DO concentration of each. The DO electrode and stirring boot must be thoroughly rinsed with distilled water after each bottle's initial DO concentration is determined so that there will not be any carryover of contaminates from bottle to bottle.

7. Place the rack(s) of bottles into the BOD incubator, leave them there undisturbed, for 5 days at 20.0°± 1.0°C.

5.2.8 Obtaining Results

5.2.8.1 Final DO Readings

1. Read and record the DO of all bottles after the 5-day incubation period using the methods described in Step 1 of Section 5.2.7.3, "Initial DO Readings." There is no need to rinse the electrode and stirring boot between sample readings in this part of the procedure.

2. Record the final DO results in their respective places on the BOD bench sheet.

3. Subtract the 5-day final DO readings from the initial DO readings.

   NOTE If the depletion of all three dilution water blanks is greater than 0.2 mg/L, the test results must be discarded. In this case, the method of washing labware may be inadequate, or the distilled water used may be of a poor quality. Ensure that the problem(s) is/are corrected.

5.2.8.2 Calculating Seed Factor

1. Once the depletions of the three seed control bottles are obtained (Initial DO - Final DO), a seed factor can be calculated. Divide each depletion by the % concentration of each of the respective bottles.

2. Using only those seed control bottles that gave a depletion of at least 2 mg/l and a residual of at least 1 mg/l DO, figure the seed factor by averaging those that meet the criteria. Do this by taking each depletion times the amount of seed added to those seeded samples (i.e., 4.0 ml) and divide by the % concentration of that seed control bottle. Write the answers on the bench sheet under the seed factor column and average them.

3. Write the obtained (average) seed factor on the bench sheet in the seed factor spaces for each of the sample bottles that had seed added to them.

5.2.8.3 Finding Final Depletion

1. Find the final depletion of those bottles containing seeded samples by subtracting the average seed factor from each depletion.

2. The final depletion of those bottles containing unseeded samples is found by simply using the depletion amount; carry those same amounts to the final depletion spaces.

5.2.8.4 Finding BOD, mg/l and Average BOD, mg/l

1. Take each final depletion and divide by % concentration (% concentration in its decimal form).

2. Average the BOD, mg/l using only those samples that have a depletion of at least 2 mg/l with at least 1 mg/l remaining. The final depletion after 5 days must be within the recommended 40-70 percent range. (Final Depletion/Initial DO X 100 = recommended depletion range percentage.)

5.2.9 Calibration of Dissolved Oxygen Electrode

5.2.9.1 The dissolved oxygen probe should be calibrated each day that it is used. At the end of a series of dissolved oxygen measurements, the calibration should be checked to ensure that it has been maintained within 0.2 mg/l.

5.2.10 Saturated Water Method

5.2.10.1 Aerate a BOD bottle of H_2O for at least 15 minutes at a relatively constant temperature.

5.2.10.2 Place the probe in the sample and stir.

5.2.10.3 Switch the unit to TEMPERATURE and record the reading. Refer to the calibration tables on the back of the unit for the PPM value corresponding to the temperature reading.

5.2.10.4 MacDill AFB is less than 500 feet in altitude, therefore the altitude correction factor will always be 1.00.

5.2.10.5 Multiply the PPM value according to temperature by the correction factor of 1.00.

5.2.10.6 Switch to the PPM lever on the unit and adjust the calibration knob until you reach the corrected value determined in 5.2.10.5.

5.2.10.7 Leave the probe in the sample for <u>two minutes</u> to verify stability of calibration. Readjust if necessary.

5.2.11 Air Calibration Method

5.2.11.1 Place the probe in a partially filled BOD bottle. Do not put more than 50 mls of water in the bottle.

5.2.11.2 Switch to TEMPERATURE and allow the probe to stabilize for a period of at least 15 minutes.

5.2.11.3. Determine PPM value for the temperature. Refer to the calibration tables on the back of the unit for the PPM value corresponding to the temperature reading.

5.2.11.4 Multiply the PPM value for the temperature achieved by the altitude correction factor for MacDill, which is 1.00.

5.2.11.5 Switch to the appropriate PPM range and adjust the calibration knob until the meter reads the corrected value. Leave the probe in the sample for two minutes to verify stability. Readjust if necessary.

5.3 TOTAL SUSPENDED SOLIDS ANALYSES

5.3.1 Scope and Application

This method covers the determination of total suspended solids. Total suspended solids is a measure of the effectiveness and efficiency of many wastewater treatment processes and plants as a whole. The effluent total suspended solids from the MacDill AFB WWTP is limited by the reclaimed water permit. The permit requires a specified frequency of analysis for total suspended solids. Suspended solids encompass the portion of total solids retained after filtration.

5.3.2 Methodology

5.3.2.1 Specific Method Utilized

This method was developed as a sequential, step-by-step procedure and is derived directly from Method 2540 D, p. 2-56 of *Standard Methods For The Examination of Water and Wastewater*, 18th Edition; 1992.

5.3.2.2` Summary of Method

A well-mixed sample is filtered through a weighed, standard, glass-fibered filter, and the residue retained on the filter is dried to a constant weight at 103-105°C. The increase in weight of the filter represents the total suspended solids.

5.3.3 Interferences:

5.3.1.1 Large floating or submerged agglomerates of nonhomogeneous materials in the sample should be excluded if it is determined that their inclusion is not desired in the final result.

5.3.1.2 Limit the sample size to yield no more than 200 mg of residue, because the excessive residue may form a water entrapping crust.

5.3.1.3 For those samples that contain great amounts of dissolved solids, thoroughly rinse the filter to remove the dissolved material.

5.3.1.4 Weighing boats (pans) should always be handled with forceps; the grease off of fingertips will throw the results off, thus producing a higher, false weight.

5.3.4 Apparatus and Materials

5.3.4.1 Apparatus

1. Vacuum pump
2. Filtering flask and vacuum tubing
3. Filter funnel assembly
4. Desiccator with dry desiccant
5. Analytical balance, capable of weighing to 0.1 mg.
6. Rinse bottle containing distilled water
7. Forceps
8. Drying oven
9. TSS Bench Sheet (see Appendix A)
10. Graduated cylinder

5.3.4.2 Materials

1. Aluminum weighing boats (pans)
2. 47 mm glass fiber filters (Whatman 934AH; Gelman A/E; Millipore 4. AP40; or equivalent)
3. Pen

5.3.5 Procedure

5.3.5.1 Preparation of the Glass Fiber Filter

1. Place the glass fiber filter on the base of the filter funnel assembly with the wrinkled side upward. Use forceps to handle the filter. Note: Filters and weighing boats must be handled throughout this entire procedure with forceps.

2. Apply vacuum to the flask using the vacuum pump and tubing. Wash the entire surface area of the filter using three 20-ml portions of distilled water. Continue the suction for 2 minutes to remove all traces of water.

3. Cut off the vacuum and remove the filter. Place the filter in a numbered, aluminum weighing boat.

4. Repeat Steps 1-3 for the remaining filters.

5. Place the weighing boats and filters in the drying oven at a temperature of 103-105°C for one hour.

6. Remove the weighing boats and filters from the oven, and place in the sealed desiccator. Allow the filters to cool for 30 minutes.

7. Using the analytical balance, weigh and record the weights of each weighing boat and filter.

8. Repeat Steps 5-7 (as many times as it takes) to obtain a constant weight, or until the weight loss is less than 0.5 mg between successive weighings.

5.3.5.2 Sample Analysis

1. Remove the glass fiber filter from the weighing boat, using forceps, and place it on the base of the filter funnel assembly that is contained in the filtering flask. Ensure the filter is placed on the filter funnel assembly's base with the wrinkled side up.

2. Place the filtering funnel upon the filter and base of the filtering funnel.

3. Apply vacuum to the flask and filter a well-mixed, measured volume of sample through the filter. Record the volume of sample filtered on the bench sheet. Continue to apply suction for 2 minutes to ensure all traces of water are removed. Note: Cleaner samples, such as effluents, should be filtered before dirtier samples.

4. Rinse the measuring devise (graduate cylinder) with approximately three 20-ml portions of distilled water, and pour the rinsings into the filtration unit. Using the wash bottle, rinse the entire wall area of the filtering funnel thoroughly. Note: Allow complete drainage between rinsings.

5. Apply suction for an additional 2 minutes to ensure all traces of water are removed.

6. Remove the filter from the unit, using forceps, and place into the weighting boat.

7. Repeat Steps 5-7 as described in Section 5.3.5.1, "Preparation of the Glass Fiber Filter," until a constant weight is obtained, or until the weight loss is less than 4 percent of the previous weight (0.5 mg, whichever is less).

5.3.5.3 Calculating Total Suspended Solids, mg/l

$$\text{TSS mg/l} = \frac{\text{A - B X 1,000,000}}{\text{Sample Volume, ml}}$$

Where: A = Weight of the filter and weighing boat + dried residue, g.

and

B = Weight of the filter and weighing boat, g.

5.4 FECAL COLIFORM MEMBRANE FILTER PROCEDURE

5.4.1 Scope and Application

This method covers the determination of fecal coliform bacteria density. Fecal coliform bacteria are an indicator organism that provides a measure of the effectiveness of the disinfection process of wastewater treatment plant. The effluent Fecal Coliform bacteria discharge from the MacDill AFB is limited by the reclaimed water permit and the permit contains a specific frequency of analyses.

5.4.2 Methodology

5.4.2.1 Specific Method Utilized

This method was developed as a sequential, step-by-step procedure and is derived directly from Method 9222D, P9-60 of *Standard Methods for the Examination of Water and Wastewater*, 18th Ed., 1992.

5.4.2.2 Summary of Method

The Membrane Filter (MF) Coliform Method is a fast, simple way of estimating bacterial populations in water. A well-mixed sample volume is passed through a membrane filter with a pore size small enough (0.45 microns) to retain the bacteria present. The filter is placed on an absorbent pad (in a petri dish) saturated with a culture medium that is selective for coliform growth. The petri dish containing the filter and pad is incubated, upside down, for 24 hours at 44.5°C ± 0.2°C. After incubation, the colonies that have grown are identified and counted by using a low-power microscope.

5.4.3 Supporting Materials and Equipment

5.4.3.1 Apparatus and Materials

1. Clippers, large
2. Graduated cylinders, 100 ml
3. Petri dishes, sterile
4. Filter holder
5. Filter pump
6. Membrane filters, pre-sterilized in lab autoclave or commercially available

7. Filter flask, 500 ml
8. Forceps, flat-end, 110 mm
9. Pads, sterile, commercially available or pre-sterilized in lab autoclave
10. Pipettes, sterile, 10 ml
11. Tubing, rubber
12. Incubator - water bath or heat sink 44.5 ± 0.2°C
13. Microscope, 10x - 15x magnification

5.4.3.2 Reagents

1. Dechlorinating Reagent Powder Pillows or 10% Solution of Sodium Thiosulfate.
2. M-FC Medium, commercially prepared
3. 70% Isopropyl Alcohol
4. Phosphate buffer solution

5.4.4 Analytical Procedures

5.4.4.1 Sterilization of Equipment

1. Before starting the test, preheat the autoclave to 121C,° and wash all sample bottles, graduated cylinders and containers, forceps, filter flasks, and filter holder in hot, soapy water. Rinse several times with tap water, then with demineralized water, and dry thoroughly. Prior to sterilization, prepare items as follows, then sterilize in an autoclave at 121°C for 15 minutes.
2. Sample bottles should be capped and covered with brown Kraft paper.
3. Forceps should be wrapped in brown paper and sealed with masking tape.
4. The opening of the graduated cylinder and the filter flask should be covered with metal foil or brown paper.
5. The two parts of the filter should be wrapped separately in brown paper and sealed with masking tape.

5.4.4.2 Preparation of Phosphate Buffer Solution

1. Phosphate Buffer. The phosphate buffer is used to dilute and rinse samples. This solution must be sterile, because any organisms present in the buffer may interfere with coliform counts. Prepare the buffer by:

2. Stock Solution I. Dissolve 34.0 grams of potassium dihydrogen phosphate (KH_2PO_4) in 500 ml of laboratory pure water. Adjust the pH to 7.2 with 1 N NaOH. Dilute to 1000 ml with laboratory pure water to produce 1 L of stock buffer solution. Refrigerate stock buffer. Discard it if it becomes turbid.

3. Stock Solution II. Dissolve 28 grams of magnesium chloride ($MgCl_2$) or 81.4 gram of $MgCl_2.6H_2O$) in 1 L of laboratory pure water.

4. Working Solution. Add together 1.35 ml of Stock Solution I and 5.0 ml of Stock Solution II and dilute to 1 L with laboratory pure water in an aspirator bottle. Mix completely.

5.4.4.3 Equipment and Material Preparation

1. Prior to preparing the sample set-ups, wipe down the countertop being used with isopropyl alcohol.

2. Set out petri dish for each sample to be tested. Put sterile pad into each dish.

3. Prior to opening, dip the etched end of a M-FC Medium Ampoule in 70% isopropanol alcohol for 1 minute. Allow the alcohol to evaporate.

4. Snap open the neck of the ampoule, being careful not to touch the area surrounding the etched mark.

5. Pour the M-FC Medium evenly over the absorbent pad in the petri dish.

6. Unwrap the forceps, filter holder, filter flask, and graduated cylinder.

7. Attach the rubber tubing to the filter pump and place the bottom half of the filter holder in the neck of the filter flask.

8. Dip the end of the forceps in 70% isopropyl alcohol for one minute.

9. Open a package of sterile membranes. Using the sterile forceps, carefully center a sterile filter on the porous plate of the filter apparatus. Be sure the grid side is up.

10. Carefully put the top half of the filter holder in place over the filter, and clamp the holder together.

5.4.4.4 Sample Preparation and Filtration

1. Collect at least 250 ml of water from a representative effluent site. Sample containers should be wide-mouth glass or polypropylene bottles that have been carefully cleaned and rinsed with demineralized water, then sterilized in the autoclave. To avoid contamination during sampling, do not handle the stopper or neck of the sample bottle. Keep container closed until ready to use, then fill without rinsing and replace the cap immediately. Be sure to leave at least 1 inch of head space above the sample in the container. For chlorinated samples, add the contents of one Dechlorinating Reagent Pillow or 0.2 ml of a 10% solution of Sodium Thiosulfate to each sample bottle to counter any residual chlorine that may be present prior to sterilizing in the autoclave.

2. Shake the sample bottles to distribute the bacteria evenly, then measure the sample into the sterile graduated cylinder. Add a small volume of sterile buffer dilution water to filter funnel and graduated cylinder.

3. Prepare a minimum of three dilutions. Dilutions of 10% (10 ml), 1% (1 ml) and 0.1% (0.1 ml) should be used initially. If necessary, dilutions should be adjusted to obtain membrane filter counts between 20 and 60 colonies. A sterile buffer dilution water blank should be prepared first, then the smallest dilution next, and so forth (weakest to strongest). A known positive sample should be set up last to test for the viability of the test.

4. Pour the sample into filter holder, turn on vacuum and filter. Rinse the filter holder with three 20- to 30-ml portions of sterile buffer dilution water. Allow to vacuum. Turn off the pump.

5. Dip forceps in 70% isopropyl alcohol for 1 minute, then air dry. Remove the filter holder and immediately peel off the filter with sterile forceps. Place the filter on the absorbent pad. Avoid entrapping air under the filter when placing it on the absorbent pad.

6. Replace cover on petri dish and label. Inspect membrane filter after 20 seconds to insure even coloration. Place the petri dishes in the incubator in an inverted position and incubate for 22 to 24 hours at 44.5°C ± 0.2°C.

5.4.4.5 Counting Membrane Filter Colonies

Membrane filter colonies are best counted with a magnification of 10 to 15 diameters and the light source adjusted to give maximum sheen. A binocular wide field dissecting microscope is recommended as the best optical system. However, a small fluorescent lamp with magnifier is acceptable. Colony differentiation is best made with white fluorescent light.

5.4.4.6 Calculation of Coliform Density

Report the coliform density in terms of coliforms/100 ml. Compute the count, using membrane filters with 20-60 coliform colonies per membrane, by the following equation:

$$\text{Coliform colonies/100 ml} = \frac{\text{Coliform Colonies counted}}{\text{ml Sample Filtered}} \times 100$$

5.5 pH ANALYSES

5.5.1 Scope and Application

This method covers the determination of pH in aqueous samples and is applicable to drinking, surface, and saline waters, domestic and industrial wastes. The effluent pH from the MacDill AFB WWTP is limited by the reclaimed water permit. The permit requires a specified frequency of analysis for pH.

5.5.2 Methodology

5.5.2.1 Specific Method Utilized

This method was developed as a sequential, step-by-step procedure and is derived directly from Method 4500-H, p. 4-65 of *Standard Methods For The Examination of Water and Wastewater*, 18th Edition; 1992, and *Method E150.1, Methods for Chemical Analysis of Water and Wastes*, EPA-600/4-79-020, March 1983.

5.5.2.2 Summary of Method

A well-mixed sample is poured into a beaker with a magnetic stir bar. A pH probe is lowered into the sample, and the pH and temperature are read and recorded.

5.5.3 One Buffer Calibrations

5.5.3.1 Immerse the electrodes into the pH buffer to be used for calibration and release the STANDBY button and depress the pH button. Measure the temperature of the buffer solution and set the Temperature Control to this value. Turn outer slope knob to 100 and inner knob (M130 only) fully clockwise.

5.5.3.2 Adjust the CALIBRATION control until the readout displays the pH value of the buffer solution.

5.5.3.3 Remove the electrodes from the buffer solution by moving the electrode holder up. Rinse the electrodes with distilled water to prevent carryover of the buffer.

5.5.3.4 Assure that the temperature of the sample solution is the same as that of the buffer solution for calibration. If it is not, adjust the Temperature Control to the temperature of the unknown sample.

5.5.3.5 Lower the electrodes into the unknown sample solution. The display now indicates the pH of the unknown. If the pH value of the unknown is not within ±3 units of the pH value of the calibrating buffer, a two point calibration should be performed.

5.5.3.6 After measurement, raise and rinse the electrodes with distilled water. Repeat Step 5 for additional unknowns.

5.5.4 Two Buffer Calibration

5.5.4.1 In this procedure, two buffer solutions or different pH values are utilized. The one point calibration is performed at pH 7 as outlined above, and a second calibration is performed at a different pH.

This procedure, which will assure greater accuracy, may be used with manual or automatic temperature compensation.

5.5.4.2 Perform the one point calibration in 5.5.3 through Step 3.

5.5.4.3 Immerse the electrodes into the second buffer solution of known pH value and temperature. If the temperature of the second buffer differs from the first, this should be compensated for, either manually or automatically if the ATC is being used.

5.5.4.4 Adjust both the outer and inner (M130 only) Slope knobs (as required) until the readout displays the pH value of the second buffer.

5.5.4.5 Raise electrodes, rinse, and make measurements of unknown solutions.

5.5.5 pH Measurements Using the ATC

5.5.5.1 Turn the TEMP °C control fully counterclockwise until an audible click is heard and the indicator points to ATC.

5.5.5.2 Plug the Automatic Temperature Compensator connector into the input provided at the rear of the instrument. Place the compensator, pH and reference electrodes into a buffer solution of known pH value.

5.5.5.3 Depress the operate and pH buttons. Turn the outer slope knob to 100 and the inner knob fully clockwise.

5.5.5.4 Adjust the CALIBRATION control until the readout displays the pH value of the buffer solution.

5.5.5.5 Remove the electrodes from the buffer solution and rinse with distilled water or the unknown sample to be measured.

5.5.5.6 Immerse the electrodes and the ATC probe into the sample solution and read the pH value from the digital display

5.6 CHLORINE RESIDUAL - COLORIMETRIC METHOD

5.6.1 Scope and Application

5.6.1.1 This method is applicable to the measurement of total, free or combined residual chlorine in water or wastewater samples.

5.6.1.2 Concentrations of residual chlorine from 0 to 2.00 mg/l may be measured directly.

5.6.1.3 The total residual chlorine in the effluent from the MacDill AFB WWTP is limited by the reclaimed water permit. The permit requires a specific frequency of analysis for residual chlorine.

5.6.2 Methodology

5.6.2.1 Specific Method Utilized

This method was developed as a sequential step-by-step procedure and is derived directly from Method 4500-ClG, page 4-45 of *Standard Methods For The Examination of Water and Wastewater*, 18th Edition; 1992.

5.6.3 Summary of Method

Chlorine can be present in water as free available chlorine and as combined available chlorine. Both forms can exist in the same water and be determined together as the total available chlorine. Free chlorine is present as hypochlorous acid and/or hypochlorite ion. Combined chlorine exists as monochloramine, dichloramine, nitrogen trichloride, and other chloro derivatives. The combined chlorine oxidizes iodide in the reagent to iodine. The iodine reacts with DPD (N, N-diethyl-p-phenylenediamine) along with free chlorine present in the sample to form a red color which is proportional to the total chlorine concentration. To determine the concentration of combined chlorine, run a free chlorine test. Subtract the results from the results of the total chlorine test to obtain combined chlorine.

5.6.4 Total Residual Chlorine

5.6.4.1 Apparatus and Materials

1. 50-ml beaker
2. Sample cell holders

3. Pocket Colorimeter

4. DPD Total Chlorine Powder Pillows

5.6.4.2 Calibration

The Pocket Colorimeter is factory calibrated to save the analyst the time and expense required to construct their own calibration curve. It is ready for use without calibration by the user. As an additional benefit to the user, the Pocket Colorimeter will accept a user calibration should a regulatory official or agency request the analyst check or reconfirm the calibration in use. The following calibration section will show how to perform calibrations to meet these regulatory requests.

The instrument accepts two user-entered, two-point calibrations. One calibration is for the 0 to 4.5 mg/L (high range) Total Chlorine test. The other calibration is for the 0 to 2.00 mg/L Free Chlorine and Total Chlorine tests. The instrument uses these user-entered calibrations to determine the chlorine concentration of measured samples. To perform a user calibration, a chlorine standard solution must be made (a sample of known chlorine concentration can be used). Then, DPD reagents must be used to develop the color in the standard solution or the known sample. For either calibration range, the chlorine concentration of the solution must be between 1.60 to 2.00 mg/L Cl_2 (1.6 to 2.0 mg/L for the high range). In addition, the concentration of the prepared chlorine standard or sample must be determined with an alternate laboratory instrument such as a spectrophotometer (Hach DR/3000, DR/2000), another colorimeter (Hach DR/700) or by amperometric titration. The manufacturer's recommendations for calibration should be followed explicitly.

5.6.5 Free Residual Chlorine

5.6.5.1 Procedure

1. Fill a 10-mL cell to the 10-mL line with sample. Samples must be analyzed immediately and cannot be preserved for later analysis.

2. Ensure the instrument is in the high range mode. Press the ZERO or READ key. The display will read to the tenth place (0.0, not 0.00) if it is in high range mode.

3. Add the contents of two DPD Total Chlorine Powder Pillows to the sample cell (the prepared sample). Cap the cell and shake gently for 20 seconds. Shaking the cell gently dissipates bubbles which may form in samples containing dissolved gases.

4. Wait 3 minutes. During this period, proceed with Steps 4-8. A pink color will develop if chlorine is present. Accuracy is not affected by undissolved powder.

5. Insert the 1-cm cell adapter into the instrument by aligning with tabs on the adapter with the slots in the right side of the cell holder.

6. Fill a 1-cm sample cell with sample (the blank). Capping the sample cell is optional. If using uncapped cell, be sure that no liquid is spilled into the instrument.

7. Place the blank in the cell holder. For best results, zero the instrument and read the sample under the sample lighting conditions.

8. Cover the sample cell with the instrument cap (flat side should face the back of the instrument). Be sure the cap fits tightly against the instrument.

9. Press: ZERO. The instrument will turn on and the display will show --- followed by 0.0. High range only displays to tenths of mg/L. The instrument automatically shuts off after 1 minute. If this occurs, the last zero is stored in memory. Press READ to turn the instrument on and complete sample analysis.

10. Fill a 1-cm cell with the solution from the 10-mL cell in Step 3.

11. Within three minutes after the 3 minute period, place the prepared sample in the cell holder.

12. Cover the cell with the instrument cap (flat side should face the back of the instrument). Be sure the cap fits tightly against the instrument.

13. Press: READ. The instrument will show --- followed by the results in mg/L chlorine ($C1_2$).

14. If the sample temporarily turns yellow after reagent addition or shows overrange (flashing 5.0 in display), dilute a fresh sample and repeat the test. A slight loss of chlorine may occur because of the dilution. Multiply the result by the appropriate dilution factor.

5.7 TURBIDITY

5.7.1 Scope and Application

This method covers the determination of turbidity in plant effluents, treated drinking water supplies and surface water samples. The effluent from the MacDill AFB WPCP effluent turbidity is limited by the reclaimed water permit and the permit requires a specific frequency of analyses.

5.7.2 Methodology

5.7.2.1 Specific Method Utilized

This method was developed as a sequential, step-by-step procedure and is derived directly from Method 2130 B, p. 2-9 of *Standard Methods For The Examination of Water and Wastewater*, 18th Edition; 1992.

5.7.2.2 Summary of Method

This method is based on a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. The higher the intensity of scattered light, the higher the turbidity.

5.7.3 Interferences

Turbidity can be determined for any water sample that is free of debris and rapidly settling coarse sediments. Dirty glassware, the presence of air bubbles, and the effects of vibrations that disturb the surface visibility of the sample will give false results. "True color," that is, water color due to dissolved substances that absorb light, causes measured turbidities to be low. This effect usually is not significant in the case of treated water.

5.7.4 Apparatus and Materials

5.7.4.1 Apparatus

1. *Turbidmeter* consisting of a nephelometer with a light source for illuminating the sample and one or more photoelectric detectors with a readout device to indicate intensity of light scattered at 90° to the path of incident light.

2. *Sample tubes*, clear colorless glass. Keep tubes scrupulously clean, both inside and out, and discard when they become scratched or etched. Never handle them

where the light strikes them. Use tubes with sufficient extra length, or with a protective case, so that they may be handled properly. Fill tubes with samples and standards that have been agitated thoroughly and allow sufficient time for bubbles to escape.

5.7.4.2 Materials

1. *Turbidity-free water:* Turbidity-free water is difficult to obtain. The following method is satisfactory for measuring turbidity as low as 0.02 NTU.

2. *Stock turbidity suspension:*

   a) Solution I - Dissolve 1.000 g hydrazine sulfate (CAUTION: *Carcinogen; avoid inhalation, ingestion and skin contact.*), $(NH_2)_2 \cdot H_2SO_4$, in distilled water and dilute to 100 mL in a volumetric flask.

   b) Solution II - Dissolve 10.00 g hexamethylenetetramine. $(CH_2)_6N_4$, in distilled water and dilute to 100 mL in a volumetric flask.

   c) In a 100-mL volumetric flask, mix 5.0 mL Solution I and 5.0 mL Solution II. Let stand 24 h at 25 ± 3°C, dilute to mark, and mix. The turbidity of this suspension is 400 NTU.

   d) Prepare solutions and suspensions monthly.

3. *Standard turbidity suspension:* Dilute 10.00 mL stock turbidity suspension to 100 mL with turbidity-free water. Prepare daily. The turbidity of this suspension is defined as 40 NTU.

4. *Alternate standards:* As an alternative to preparing and diluting formazin, use commercially available standards such as styrene divinylbenzene beads÷ if they are demonstrated to be equivalent to freshly prepared formazin.

5. *Dilute turbidity standards:* Dilute portions of standard turbidity suspension with turbidity-free water as required. Prepare daily.

5.7.5 Procedures

5.7.5.1 Calibration of Turbidimeter

Follow the manufacturer's operating instructions. In the absence of a precalibrated scale, prepare calibration curves for each range of the instrument. Check accuracy of any supplied calibration scales on a precalibrated instrument by using appropriate standards.

5.7.5.2 Measurement of Turbidity Less than 40 NTU

Thoroughly shake sample. Wait until air bubbles disappear and put sample into turbidimeter tube. When possible, put shaken sample into turbidimeter tube and immerse it in an ultrasonic bath for 1 to 2 minutes, causing complete bubble release. Read turbidity directly from instrument scale or from appropriate calibration curve.

5.7.5.3 Measurement of Turbidities Above 40 NTU

Dilute sample with one or more volumes of turbidity-free water until turbidity falls between 30 and 40 NTU. Compute turbidity of original sample from turbidity of diluted sample and the dilution factor. For example, if five volumes of turbidity-free water were added to one volume of sample and the diluted sample showed a turbidity of 30 NTU, then the turbidity of the original sample was 180 NTU.

5.7.6 Calculation

$$\text{Nephelometric turbidity units (NTU)} = \frac{A \times (B + C)}{C}$$

where:

A = NTU found in diluted sample,

B = volume of dilution water, mL, and

C = sample volume taken for dilution, mL.

CHAPTER 6
SAFETY

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SAFETY

6.1 INTRODUCTION

A wastewater treatment plant exposes an operator to many potentially hazardous conditions; however, it need not be an unsafe place to work. Adherence to safety rules and common sense are generally sufficient to protect the operator from injury.

The MacDill AFB wastewater treatment plant contains various potential hazards similar to those existing in any wastewater treatment plant. The major types of hazards associated with such a facility are:

1. A potential for occurrence of injuries.
2. Handling of hazardous chemicals.
3. Exposure to various gases at abnormal concentrations.
4. Exposure to infectious diseases.

Due to the presence of these hazards, plant personnel must exercise caution in all their activities around the wastewater treatment plant and must take the steps necessary to protect all visitors to the plant from dangers unknown to them. A good plant safety program and safe working procedures and conditions are the keys to voluntary compliance with the Occupational Safety and Health Act of 1970 (OSHA). This section describes methods for achieving these safety objectives at the MacDill AFB facility. Some of the primary benefits of an effective safety program include lower operating costs, improved treatment efficiency, good employee morale, and positive community relations.

A constant conscious effort must be made both by plant management and by plant personnel to maintain a safe working environment. Every accident, injury, or work-related illness serves as an indication that there is a problem either with plant design, equipment specification or function, standard plant procedures, or employee assignment, capabilities, or training. Ideally, such problems should be recognized and remedied prior to occurrence of any undesirable situations. However, if an accident should occur, the source of the problem should be sought out and remedied immediately.

MacDill AFB currently has a detailed safety program for the WWTP. Safety procedures are based on AFOSH Safety Standards. A work place hazard analysis of the

WWTP and related job tasks has been performed. From the hazard analysis, specific safety procedures have been developed. Examples of these specific procedures include:

- Safe handling of chlorine cylinders,
- Changing chlorine gas cylinders,
- Working around open tanks,
- Chemical handling, and
- Working around operating mechanical and electrical equipment.

Other aspects of the MacDill AFB WWTP safety program include:

- Provision of appropriate personal protective equipment for plant personnel,
- Emergency procedures for activities such as fire reporting, personnel evacuation and personnel injury.

This section of the O&M Manual is designed to present additional safety-related topics and to augment current procedures. Further references in the area of safety for the MacDill WWTP can be obtained from the Water Environment Federation. Some pertinent references include:

- SM-2, Guidelines for Developing a Plant Safety Program.
- MOP-1, Safety and Health.

6.2 IMPACT OF REGULATIONS ON SAFETY/GENERAL CONSIDERATIONS

The OSHA regulations, which became law in 1971, were implemented to eliminate unsafe working conditions in American industries. Portions of this law are applicable to wastewater treatment works and cover the activities of both the management and operations personnel.

6.2.1 Management Responsibilities

Plant management is responsible for the development, implementation, and administration of the health and accident prevention program. These duties include, but are not limited to, the following:

1. Provide the leadership necessary to assure and maintain employee interest and participation.
2. Be familiar with job requirements, plant layout, facilities, fire protection systems, and fire prevention needs to the degree that unsafe acts or unsafe conditions can be recognized, discussed, and corrected.
3. Be the focal point for coordination and review of accident investigations and reports.
4. Review and select applicable safety materials for display or distribution.
5. Cooperate and assist with outside agencies that need to inspect, survey, or acquire knowledge of specific operations (Occupational Safety and Health Administration [OSHA] compliance officers, health officials, fire department personnel, Air Force inspectors, and so on).
6. Review the safety program periodically and amend it when necessary.
7. Require that employees adhere to safe procedures in the performance of their job.

In addition to the above responsibilities, management must ensure that the workplace is free from identifiable hazards which could cause physical injury, disease, or death. Potential hazard points which must be examined include light, noise, walkway clutter, ventilation, defective equipment, hygiene facilities, personnel break areas, and many others.

Management also has the responsibility to provide all applicable protective equipment and tools that are required for the employees to carry out their work assignments. Protective equipment includes eye protection, body protection, and respiratory protection.

Management will also be responsible for providing safety training and instruction. This involves identifying and determining training needs and objectives. Efforts include hands-on and classroom training conducted by in-plant personnel. It also includes

training by safety professionals (Red Cross, Fire Department), equipment and chemical suppliers, and other outside sources. Some of these types of programs are currently in place at the MacDill WWTP and should be continued. Additional training by equipment and chemical suppliers should also be pursued.

6.2.2 Employee Responsibilities

The regulations outline responsibilities for the employees to follow. As mandated by OSHA, these occupational and safety standards are applicable to the actions of the staff in carrying out the assigned job duties. The employee must be a positive influence on the safety program. Each employee is the person most concerned for his/her safety and must assume certain duties and responsibilities to assure on-the-job safety. These include, at a minimum:

1. Knowing his/her job and applying safe work practices as guided by published plant work rules or procedures.
2. Recognizing the hazards of the job and taking precautions to ensure his/her safety and the safety of those around him/her.
3. Informing his/her supervisor of hazards or unsafe acts and making recommendations as to how to eliminate or minimize those hazards.
4. Actively participating and cooperating in the overall safety program.
5. Maintaining cleanliness at the job station and maintaining good personal health habits.
6. Reporting to work well-rested so that he/she is in a good state of mind, receptive to instructions, and physically capable of doing the job.

6.2.3 Safety Inspections

Regular safety inspections must be performed to ensure that a safe work environment is maintained within the plant. Inspections should be performed monthly. The purpose of the inspection is to detect, identify, and control hazards before accidents occur.

Safety checklists should be developed for specific areas (tanks, pump stations) or items (fire extinguishers, first aid kits, and safety showers). The lists should be simple and brief and should not include unnecessary items. Unsafe conditions encountered during the inspection should be corrected in the most timely and cost-effective manner.

Hazardous conditions should be immediately brought to the attention of the WWTP Superintendent. All hazardous areas should be documented on AF Forms 457, USAF Hazard Report.

6.2.4 Accident Investigation and Reporting

All accidents, injuries, and work-related illnesses must be reported immediately to the WWTP Superintendent. This will provide compliance with laws and regulations designed to protect both the employer and the employee, as well as insuring that prompt and effective first aid, medical, or hospital treatment is given to the employee. Prompt reporting may help to reduce the severity of the injury as well as the amount of time lost off the job. The filing of a complete report serves two primary purposes. It serves as a record of the incident which can be used in settling any claims, and it is used by plant administration in determining what changes should be made to help prevent accidents, injury, or illness. On-the-job injuries should be reported to the Civilian Personnel Officer using Form CA-1. Near accidents should also be reported, as they may indicate an unsafe condition which should be corrected. A critical aspect of any safety program is an effective system for accident investigation, accident reports, report analysis, and corrective action.

6.3 PLANT PROTECTIVE DEVICES

Several structures and devices have been incorporated into the MacDill AFB wastewater treatment plant design for the express purpose of providing a measure of safety to plant employees. It is imperative that these structures and devices be utilized consistently. The use of preventive measures to avoid accidents is highly preferable to the necessity for responsive measures.

6.3.1 Handrails

Hand railings and hand chains are provided on walkways around and over tanks, specifically at the final clarifiers, headworks, aeration tanks, digesters, tertiary filters, and chlorine contact tank. These serve to protect plant employees from falls during routine operation inspections, particularly when surfaces are slippery. These devices are for the safety of operators and visitors and should not be bypassed by climbing over or cutting. Flotation rings are provided at the headworks, final clarifiers, and digesters for use in case personnel fall into the tanks.

6.3.2 Walkways

Caution must be exercised on elevated walkways. Operators should visually check to see if all grates are level and in place before walking across them.

Anytime a walkway grating is removed for any reason, temporary barriers should be placed around the open area. Brightly colored tape or cloth should also be used to warn and protect the unwary.

6.3.3 Belt and Coupling Guards

All rotating and moving equipment is protected with belt and coupling guards and other safety devices. Guards are installed to keep anyone from accidentally getting clothes, tools, or bodily parts in contact with moving machinery. Guards are also installed to protect employees should a piece of belt, coupling, or other part break loose and be slung out of the machinery. Guards must be periodically checked for proper installation. They must never be removed while the machinery is in operation. Guards must never be left off "temporarily" for convenience reasons. Any missing guard must be replaced as soon as possible.

6.3.4 Safety Signs

Warning signs, properly placed, serve as reminders to the thoughtless and uninformed. The instructions outlined on all safety warning signs must be strictly obeyed. Care should be taken never to block the view of such signs, and any safety signs which have become illegible should immediately be replaced. Never take for granted that all activities can be performed in any given area. Every worker should read and understand all signs in the area in which he/she is working.

Flammable and explosive conditions can exist in some plant structures due to gases given off by the wastewater. "NO SMOKING" signs must be strictly obeyed. "EAR PROTECTION REQUIRED," "DANGER CHLORINE," and "DANGER, HIGH VOLTAGE" signs must also be strictly obeyed.

6.3.5 Fire Extinguishing Equipment

Fire fighting equipment (fire extinguishers) have been placed at the MacDill AFB wastewater plant. It is imperative that all personnel be familiar with the location and proper use of all fire fighting equipment.

Fire extinguishers are currently located at the following location:

- Main Control Building (2)

Regular monthly inspections of this equipment must be made to assure that all units are functional and that all fire extinguishers contain a full charge. Annual inspections should also be performed by an outside contractor. Hydrostatic testing of fire extinguishers should also be conducted regularly, generally at 5-year intervals. In addition to these items, certain fire safety information must be posted throughout the plant, including emergency phone numbers and emergency response instructions.

Fire hazards are always present in areas where lubricants, solvents, and fuels are stored. Gasoline and other volatile liquids must be stored in containers made for the purpose. All spills from such materials must be cleaned up immediately; rags, paper, wood, or any other flammable material must not be allowed to accumulate in such storage areas. Fire extinguishers should be provided in all areas where there is electrical equipment or flammable materials.

6.4 PERSONAL PROTECTIVE DEVICES

6.4.1 Hand Protection

Cotton gloves afford protection for general handling of abrasives, sharp objects, and glassware. Where hand protection is desirable but finger dexterity is essential, surgical-type gloves are to be used. Leather work gloves are desirable when manual tasks such as shoveling and raking are necessary.

The operator is cautioned not to wear rings while working in the plant. A ring can catch on machinery or equipment and cause injury to the fingers and hands.

6.4.2 Foot Protection

Safety shoes with built-in steel toe caps must be worn where heavy objects are customarily handled or there are other foot hazards. Rubber-soled safety shoes should be worn where there is a considerable amount of water, acid, or other chemical present on the floors. Safety shoes should also provide ankle protection. Calf-high and hip-high rubber boots may be required when working in flooded areas. Rubber boots should also meet standards of toe, sole, and arch protection.

6.4.3 Body Protection

Laboratory coats, aprons, smocks, coveralls, pants, jackets, hoods, and similar garments need to be used, when indicated, for protection of the body and clothes from corrosive chemicals.

Generally, operations employees should wear long pants and long-sleeve shirts. Rain suits can be worn when working in areas where sludge, water, and wastewater may be encountered, as well as for protection from the weather.

6.4.4 Eye Protection

In the wastewater treatment plant, eye protection is necessary when working in the vicinity of operating pumps, performing maintenance, or working under or near piping, valves, and open top tanks where splashing can occur. Some form of protection must always be used in the laboratory when carrying out any operation which contains a possibility of liquid splashing.

Eye protection equipment must provide adequate protection against the particular hazards for which they are designed, and be reasonably comfortable when worn under designated conditions. Protection equipment should fit snugly and not unduly interfere with the movements of the wearer. They should have adequate durability and be capable of being disinfected and easily cleaned. Persons requiring corrective lenses should be issued prescription safety eyewear with appropriate side shields. For short periods, they can wear goggles or face shields over their own glasses.

6.4.5 Safety Shower and Eyewash Facilities

At this writing, one eyewash facility is located in the laboratory, located on the second floor of the Main Control Building. All employees should be familiar with the location and use of this equipment.

The eyewash must be maintained in good working order. Monthly inspections must be conducted to insure the proper operation of the facilities. Additionally, eyewash must be cleaned periodically to insure cleanliness. Access to the eyewash must always be kept clear in case of an emergency.

6.4.6 Noise Protection

Noise is generated at a wastewater treatment plant due to the large numbers of mechanical equipment required for the treatment processes. Prolonged exposure to excessive noise can cause hearing loss. The loss can be very slow and usually goes unnoticed until it is too late. Hearing loss from noise exposure can be permanent.

Anytime an employee is to be working in an area of excessive noise, personal protection devices must be used. There are a number of devices available including ear plugs and ear-muff type protectors. "EAR PROTECTION REQUIRED" signs must be strictly obeyed.

6.4.7 Respiratory Protection

Collection systems and wastewater treatment plants sometimes contain contaminated atmospheres that are dangerous to the respiratory system. Some of the hazards commonly found are chlorine gas, carbon monoxide gas, paint or solvent fumes, dust or particulates, hydrogen sulfide gas, and lack of oxygen. There are several kinds or types of respirators available with each one designed for a specific purpose, type of contaminant concentration, and period of time to be used. For example, respirators range from a simple dust mask to fully self-contained breathing apparatus (SCBA).

Employees must be fully trained on the job in how to wear and use respiratory devices. If respirator usage is only occasional or infrequent, a periodic skill and knowledge test is required. Ideally, this should be done monthly; at a minimum, quarterly. An outside group, such as the fire department, should be utilized to verify and augment this training. All training on SCBAs should be documented in a safety log.

All respiratory protection equipment must be inspected weekly and monthly. The respirators must be cleaned and all parts tested, inspected, and made ready for immediate operation. Procedures for inspection and storage are provided for each SCBA by the manufacturer.

6.4.7.1 Self-Contained Breathing Apparatus

When an employee must enter an atmosphere that is immediately dangerous to life, a self-contained breathing apparatus (SCBA) must be used. Such devices provide

complete respiratory protection in all toxic or oxygen-deficient atmospheres. This type of respirator includes a high pressure cylinder of air, a cylinder valve, a demand regulator, a facepiece, and tube assembly. To use, the worker adjusts the facepiece, turns on the cylinder valve, and breathes in to draw the air through the demand regulator to the facepiece. The worker must exhale to the surrounding atmosphere through the exhalation valve. This type of unit can generally only be used for 30 to 60 minutes at a time. One SCBA is provided at the MacDill AFB WWTP and is located at the chlorine feed building. One is for use at the sulfur dioxide chlorine facility and one for use in old Lab.

6.4.8 Medical Services and First Aid

The names, locations, and telephone numbers of doctors, hospitals, and emergency response services will be posted in locations of high visibility. These lists should be updated at least annually. All employees must know where these notices are posted.

At least one well-maintained first aid kit must be kept readily available in the MacDill AFB Facility. All employees should be trained in the use of the contents of the first aid kits.

Life rings are located at the headworks, final clarifiers, and digesters.

The plant has a combustive gas/oxygen meter to ensure safe entry into vaults.

Employees should maintain current certification in cardio-pulmonary resuscitation (CPR). Only these persons should attempt to administer cardiac life support. Improperly performed CPR is likely to cause serious damage to ribs and internal organs without sustaining breathing and heart functions.

Emergency numbers for the MacDill AFB wastewater treatment plant include:

Hospital/Ambulance/Emergency	-	911
Fire - on base	-	911
Air Police	-	911 3322 (nonemergency)

6.5 PERSONAL HEALTH

Because of the sometimes cramped quarters and corrosive or dangerous materials found in treatment plants, it is necessary for the operations staff to keep alert to all possible hazards when performing routine or emergency tasks. Also, remember that visitors to the MacDill AFB wastewater treatment plant are not as well informed as you are, so caution them to keep their hands off plant equipment. Discussed below are several areas of concern.

6.5.1 Hygiene/Bacterial Infection

Wastewater always presents a potential health hazard. Operators should be advised to keep fingers from the nose, mouth, and eyes. A majority of hazardous and/or infectious materials are carried on the hands of workers. Wastewater treatment plant workers can well take note of the slogan commonly used by bacteriologists, "a good bacteriologist never places his hands above his collar while at work." After work and before eating, the hands should be washed thoroughly with plenty of soap and hot water. The nails should be kept short and foreign material removed with a nail file or stiff soapy brush. When the hands are soiled, smoking pipes, cigarettes, or cigars may introduce hazardous material into the mouth.

Hazardous materials can also be transmitted to the body from contaminated tools and lab equipment. Never use the mouth to draw samples into pipettes, as this could easily cause hazardous materials to be introduced into the mouth.

Gloves should be worn to prevent infection while cleaning equipment, handling sludge, taking or handling samples, or handling any tools or equipment within the plant where they can safely be worn. Gloves are particularly important when the hands are chapped or the skin is broken from a wound.

Food and drink must be kept in the Main Control Building. Never store food in any container or refrigerator where wastewater samples are stored, as this poses grave dangers of contamination.

Cuts received while working should receive prompt first aid. All cuts, no matter how minor, should be reported.

Careful attention to the above safety rules will provide adequate protection from the hazards listed.

6.5.2 First Aid

The importance of first aid kits cannot be overemphasized. All employees must know their locations and understand the use of their contents. Prompt attention to all injuries is important. For all but minor injuries, a doctor should be called. Red Cross courses in first aid afford an excellent opportunity for training. The fire department

and/or emergency response service should be contacted immediately whenever emergency reactions involve resuscitation or emergency handling of gas mishaps.

6.6 PLANT HAZARDS AND SAFETY PROCEDURES

The following paragraphs describe hazards which could be present in certain parts of the MacDill AFB wastewater treatment plant and recommended methods to reduce those hazards. Risk of injury can be reduced by always remembering to think things through before starting a job.

6.6.1 Fire and Explosion Hazards

It cannot be overemphasized that every wastewater treatment plant operator must obey "No Smoking" signs and should be cautioned as to the danger of smoking, dropping lighted matches, burning tobacco, or using open flames in the MacDill AFB facility. An igniting spark can even be created in removing manhole covers, and explosions from this can occur.

Gasoline, solvents, and other nondomestic waste can occasionally be found in the wastewater influent. The vapors from these fluids, when mixed with air in the right proportions, can explode violently if ignited. Investigations by the National Bureau of Mines have shown that gasoline and petroleum vapors will be found in the lower portion of manholes or sewers and in greater concentration just above the liquid surface. Due regard must be made for the time of the year, the velocity and direction of the wind, and barometric conditions. They have also found that explosions of such vapors are generally extremely destructive.

In any area where explosive or flammable gases may tend to accumulate, such as manholes or confining structures, an explosimeter should be used to detect such gases prior to entering or working in such areas. Detailed safety considerations for confined spaces are discussed in Section 6.8.

Good housekeeping practices are important to fire prevention. The accumulation of rubbish should be prevented, and all oil-soaked and paint-soaked rags should be placed in covered metal containers. Direct access to all exits, stairs, and fire fighting equipment must be kept clear of any obstructions. All combustible materials must be kept away from heat sources and other ignition sources.

Each operator should be familiar with the location of the fire extinguishers. The plant staff must be trained in the use of fire extinguishers and other fire fighting equipment.

6.6.2 Gases

An ever-present danger in every wastewater treatment plant is the production and collection of noxious and/or harmful gases. These gases may also be flammable or explosive.

The following places at the MacDill AFB wastewater plant and collection system are most likely to be dangerous due to such gases:

1. Lift stations.
2. Manholes.
3. Inside any covered tank.
4. Pump rooms.
5. Chlorine Feed Building.

This list is not all-inclusive. Many other areas of the plant may contain accumulations of harmful, toxic, or flammable gases. A partial list of gases commonly found in wastewater treatment plants is provided on Table 6.1.

6.6.2.1 Hydrogen Sulfide

Due to the nature of the wastewater processed at the MacDill AFB facility, hazardous gases may be present in various areas of the plant. One of the most prevalent and dangerous gases present at wastewater treatment facilities is hydrogen sulfide (H_2S). Hydrogen sulfide is a flammable, colorless gas that is soluble in water. Hydrogen sulfide is evolved whenever the pH of a wastewater is less than 8.0 and sulfur is present in its reduced form (sulfide). Accumulation of hydrogen sulfide can occur in sewer lines, various sumps and wet wells, and poorly ventilated areas where wastewater or sludge is present.

Acute exposure may cause immediate coma, which may occur with or without convulsions. DEATH MAY RESULT with extreme rapidity from respiratory failure. The toxic action of hydrogen sulfide is thought to be due to its binding of the iron, which is essential for cellular respiration.

Table 6.1 Characteristics of Gases Common to the Wastewater Industry

Gas and chemical formula	Specific gravity	Explosive limits LEL	Explosive limits UEL	Max. safe 60-min. exposure (% vol. in air)	Max. safe 8-hr exposure (% by vol. in air)	Common properties	Physiological effects	Location of highest concentration	Most common sources	Simplest and safest method of testing
Ammonia NH_3	0.59	16	25	0.03	0.01	Colorless, sharp, and pungent	Irritates eyes and respiratory tract; toxic at 0.01%	Up high	Sewer gas	Oxygen deficiency indicator; odor
Carbon Dioxide CO_2	1.53	Non-flammable		4.0-6.0	0.5	Colorless, odorless, nonflammable; may cause acid taste in large quantities	Acts on respiratory nerves; 10% cannot be endured for more than a few minutes	Down low but may rise if heated	Sludge, sewer gas, combustion carbon and its compounds	Oxygen deficiency indicator
Carbon Monoxide CO	0.97	12.5	74.2	4.0	0.005	Colorless, odorless, tasteless, non-irritating; flammable, explosive, poisonous	Combines with hemoglobin of blood causing oxygen starvation; fatal in 1 hr. at 0.1%; unconsciusness in 30 min. at 0.25% and causes headaches in a few hours at 0.02%	Up high specifically if in presence of illuminating gas	Manufactured fuel gas, flue gas, combustion and fires	CO indicator
Chlorine Cl_2	2.49	Non-flammable		0.0004	0.0001	Yellow, green color; irritating, pungent odor; nonflammable and supports combustion	Irritates respiratory tract, causes irritation and burning of the skin, coughing, and pulmonary edema in small concentrations	Down low	Chlorine cylinder and feed line leaks	Chlorine detector
Ethane C_2H_6	1.05	3.1	15	No limit provided oxygen percentage (at least 12%) is sufficient for life		Colorless, odorless, tasteless, flammable, explosive, non-poisonous	Acts mechanically to deprive tissues of oxygen; does not support life	Down low	Natural gas	Combustibde gas indicator, Oxygen deficiency Indicator

Table 6.1 (cont)

Gasoline C_5H_{12}—C_9H_{20}	3.0-4.0	1.3	7	0.4-0.7	Varies	Color, flammable, explosive, odor noticeable at 0.03% concentration	Symptoms of intoxication when inhaled, difficult breathing and convulsions; fatal at 2.43%	Down low	Service stations, storage tanks and dry cleaning operations	Combustible gas indicator; oxygen deficiency indicator
Hydrogen Sulfide H_2S	1.19	4.3	46	0.02-0.03	0.001	Rotten egg odor in small concentrations; colorless, flammable, and explosive	Paralyzes the respiratory system; lessens the sense of smell as concentration increases; rapidly fatal at 0.2%	Down low; can be higher if air is hot and humid	Coal gas, petroleum, sewer gas and sludge gas	Lead acetate paper, lead acetate ampoules, H_2S detector
Methane CH_4	0.55	5	15	No limit providing sufficient oxygen (at least 12%) is present		Colorless, odorless, tasteless, explosive, flammable, and non-poisonous	Deprives tissues of oxygen; does not support life	At top, increasing to certain depth	Digestion of sludge	Combustible gas indicator; oxygen deficiency indicator
Nitrogen N_2	0.97	Non-flammable		—	—	Colorless, tasteless, odorless, and non-fammable	In very high concentrations, reduces oxygen intake; does not support life	Up high and sometimes in low areas	Sewer and sludge gas	Oxygen deficiency indicator
Oxygen (in air) O_2	1.11	Non-flammable		—	—	Colorless, odorless, tasteless; supports combustion	Normal air contains 20.93% O_2. Below 19% considered deficient; 13% dangerous; below 5%-7% fatal	Variable at different levels	Oxygen deficiency from poor ventilation and chemical combustion of O_2	Oxygen deficiency indicator
Sludge gas	varies	5.3	19.3	Varies with composition		Flammable, practically odorless, and colorless	Will not support life	Up high	Digestion of sludge	Combustible gas indicator, oxygen deficiency indicator

Subacute exposure results in headache, dizziness, staggering gait, excitement suggestive of neurological damage, and nausea and diarrhea suggestive of gastritis. Fortunately, recovery from subacute exposure is usually complete.

In areas where exposure to hydrogen sulfide exceeds 10 ppm, workers should wear full-face canister gas masks or air respirators. Because hydrogen sulfide is a flammable gas, workers must shut off ignition sources and use non-igniting/sparking equipment in the presence of hydrogen sulfide.

First aid for exposure to hydrogen sulfide is to call for medical aid, move victim to fresh air, give artificial respiration if breathing has stopped, or oxygen if breathing is difficult. If eyes have been exposed to hydrogen sulfide, they should be flushed with plenty of water.

6.7 ELECTRICAL MAINTENANCE SAFETY

Nearly all the equipment within the MacDill AFB facility is operated by electricity. Maintenance and day-to-day activities require personnel to handle and control this equipment. Unless safe work practices are strictly observed, serious injury or death can result.

Ordinary 120 V electricity may be fatal. Extensive studies have shown that currents as low as 10 to 15 mA can cause loss of muscle control and that 12 V may, on good contact, cause injury. Therefore, all voltages should be considered dangerous. Most electrical systems at wastewater treatment plants operate at voltages from 120 to 4000 or more. All electricity should be treated cautiously and without guessing as to the nature of the electrical circuit.

Electricity kills by paralyzing the nervous system and stopping muscular action. Frequently, electricity may hit the breathing center at the base of the brain and interrupt the transmission of the nervous impulses to the muscles responsible for breathing. In other cases, the electrical current directly affects the heart, causing it to cease pumping blood. Death follows from lack of oxygen in the body. It cannot be determined which action has taken place; therefore, a victim must be freed from the live conductor promptly by use of a dry stick or other nonconductor, or by turning off the electricity to at least this point of contact. Never use bare hands to remove a live wire from a victim or a victim from an electrical source. Next, cardio-pulmonary resuscitation or artificial respiration should be applied immediately and continuously until breathing is restored, or until a doctor or emergency medical technician arrives.

6.7.1 General Electrical Safety Rules

1. As long as you are not grounded, that is, as long as current cannot pass through your body to the ground, you are safe. While working on electrical circuits, do not touch the switch box cabinet or any other object, such as a pipe, that will give electric current a path through your body. Do not stand in water and, if possible, place a rubber mat under your feet.
2. Allow only authorized people to work on electrical panels.
3. Keep rubber mats on the floor in front of electrical panels.
4. Treat all electrical wires and circuits as "live," unless certain they are not.
5. Never work alone on energized equipment that operates at or above 480 V. When two employees work together, one can double-check the other, and there is always one employee available to de-energize circuits, apply first aid, or summon assistance in the event of a mishap.
6. Use approved rubber gloves.
7. Electrical control panels should never be opened unless the job requires it.
8. No part of the body should be used to test a circuit.

9. Always work from a firm base, as loss of balance may cause a fall onto energized busses or parts. Electrical parts should be covered with a good electrical insulator such as a rubber blanket.
10. No safety device should be made inoperative by removing guards, using oversized fuses, or blocking or bypassing protective devices, unless it is absolutely essential to the repair or maintenance activity, and then only after alerting operating personnel and the maintenance supervisor.
11. All tools should have insulated handles, be electrically grounded, or double insulated.
12. Jewelry should never be worn when working on electric circuits.
13. Use fuse pullers to change fuses.
14. Never use metal ladders, metal tape measures, or other metal tools around electrical equipment.
15. Keep wires from becoming a tripping hazard.
16. When performing electrical work, even simply energizing a piece of equipment, observe "No Smoking" signs.
17. When working around electrical equipment, keep your mind on the potential hazards at all times.

6.7.2 Holding and Locking Out Electrical Circuits

The most important safety requirement in electrical maintenance is to have and adhere to a good system for holding and locking out electrical circuits when equipment is being repaired. Unexpected operation of electrical equipment that can be started by automatic or manual remote control may cause injuries to persons who happen to be close enough to be struck.

When motors or electrical equipment require repair, the circuit should be opened at the switch box, and the switch should be padlocked in the "OFF" position and tagged with a description of the work being done, the name of the person, and the department involved.

All personnel involved in maintenance work should be instructed in the following lock out procedure:

1. Alert the proper personnel: supervisor, affected operations staff.
2. Before starting work on an engine or motor line shaft or other power transmission equipment, or power-driven machine, make sure it cannot be set in motion without your permission.
3. Place your own padlock on the control switch, lever, or valve, even though someone has locked the control before you--you will not be protected unless you

put your own padlock on it. The worker should have the only key to that padlock.

4. When through working at the end of your shift, remove your padlock or your sign and blocking, never permit someone else to remove it for you, and be sure you are not exposing another person to danger by removing your padlock or sign.
5. If you lose the key to your padlock, report the loss immediately to your supervisor and get a new padlock.
6. After repair, clear personnel from area BEFORE closing the breaker.

6.7.3 Explosion-proof Equipment

Before breaking the seal on an explosion-proof enclosure, make certain that the work area has good ventilation. A combustible vapor check should be made. Nearby equipment and facilities should be shut down if practical. The area should be continually monitored for vapors, and only non-sparking, nonferrous tools should be used. On completion of the work, make certain that the explosion-proof fittings have been adequately resealed.

6.7.4 Fire Extinguishers

At all motor control centers, transformer banks, and switchgear installations, fire extinguishers rated "Class C" for use on fires at electrical equipment should be mounted in the immediate vicinity. Water or other conductive liquids and materials that heat should never be used on electrical fires.

6.8 CONFINED SPACE SAFETY

A large percentage of the FATAL accidents that have occurred in wastewater treatment plants have occurred in confined spaces. Clearly the problem is a lack of knowledge of the dangers involved in entering and working in confined spaces and the proper procedures to follow to prevent accidents.

6.8.1 Definition of Confined Space

A "confined space" is defined as any enclosed or semi-enclosed space that has restricted means for entry and exit and is not intended for continuous occupancy. Typical confined spaces in the wastewater industry are manholes, metering stations, valve or siphon chambers, digestors, silos, empty tanks, pits or any other area in the system that has direct contact with wastewater, sludge, sludge gas, or conduits carrying these substances.

6.8.2 Classification of Confined Spaces

Confined spaces are classified based upon existing or potential hazards. The two classifications of confined spaces are nonpermit confined space and permit-required confined space. A nonpermit confined space does not contain atmospheric hazards or have the potential to contain any hazard capable of causing death or serious physical harm. Examples of nonpermit confined spaces include vented vaults or motor control cabinets. These spaces have either natural or permanent mechanical ventilation to prevent the accumulation of a hazardous atmosphere, and they do not present engulfment or other serious hazards. A permit-required space has one or more of the following characteristics:

- Contains or has the potential to contain a hazardous atmosphere.
- Contains a material that has the potential for engulfing a person.
- Has an internal configuration such that a person could be trapped by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross-section.
- Contains any other recognized serious safety or health hazard.

The plant safety representative shall evaluate the workplace to determine if any spaces are permit-required confined spaces. Procedures described in paragraphs 6.8.3 through 6.8.10 apply only to permit-required spaces. Since nonpermit spaces are free of atmospheric or safety hazards, they do not require special entry protocols. If there are changes in the use or configuration of a nonpermit confined space that could increase the hazards to the entrants, the plant safety representative shall reevaluate the space and reclassify it as a permit-required space if necessary.

6.8.3 Warning Signs

A plant that contains permit-required confined spaces must post warning signs at the entrance to these spaces. Signs must, as a minimum, contain the following language:

DANGER PERMIT-REQUIRED CONFINED SPACE DO NOT ENTER

6.8.4 Permit-Required Confined Space Entry Permit System

Employees must enter permit-required spaces in accordance with the plant's written permit-required confined space entry program. The written program shall be developed by the plant safety representative or designee and must address the following items:

- Measures necessary to prevent unauthorized entry into confined spaces.
- Methods for identifying and evaluating the hazards of the confined space prior to entry.
- Procedures and practices necessary for safe entry.
- Safety equipment necessary to conduct operations.
- Methods to evaluate space conditions during entry operations.
- Designated persons who are to have active roles in confined space operations (for example, entrants, attendants, and entry supervisor) and their duties.
- Methods to apprise contractors of precautions or procedures to implement when hired to conduct operations in a permit space.

6.8.5 Entry Permit

Entry into any area designated as a permit-required confined space will require a permit. The permit is an authorization and approval in writing that specifies the location and type of work to be done and certifies that all existing hazards have been evaluated and necessary protective measures have been taken to ensure the safety of each worker. The entry permit must address the following items:

- The permit space to be entered.
- The purpose of the entry.
- The date and the authorized duration of the entry permit.
- Names of the persons who will enter the confined space (entrants).
- Names of the persons who will be attendants.

- The name of the entry supervisor.
- The hazards of the confined space to be entered.
- The measures used to isolate the permit space and to eliminate or control the hazards before entry into the confined space.
- Acceptable entry conditions.
- The results of initial and periodic tests accompanied by the names or initial of the tester.
- The rescue and emergency services and the means used for summoning the service.
- The communication procedures used by entrants and attendants to maintain contact during the entry.
- Equipment, such as personal protective equipment, testing equipment, communications equipment, alarm systems, and rescue equipment.
- Other information necessary to ensure employee safety, given the circumstances of the particular confined space.

Once the entry has been completed, the plant safety representative will cancel the permit. Canceled permits must be maintained by the plant for at least 1 year. An example of a confined-space entry permit is included at the end of this section.

6.8.6 Equipment for Permit-Required Entry

The following is a list of equipment that must be considered prior to entering and working in permit spaces:

- Ventilation equipment needed to obtain acceptable airborne concentrations.
- Atmospheric-testing equipment to identify oxygen deficiency, combustible gases, and suspected toxic gases (e.g., hydrogen sulfide).
- Communication equipment for entrants and attendant.
- Personal protective equipment (e.g., respirators, hard hats), insofar as feasible engineering controls or work practices do not adequately protect employees.
- Lighting equipment to enable employees to work safely and exit quickly in the event of an emergency.
- Pedestrian or vehicle barriers (e.g., traffic cones, barricades, warning signs, traffic flags) to protect entrants from external hazards.
- Ladders for safe entry and egress.
- Any other equipment necessary for the entry into and rescue from the confined space.

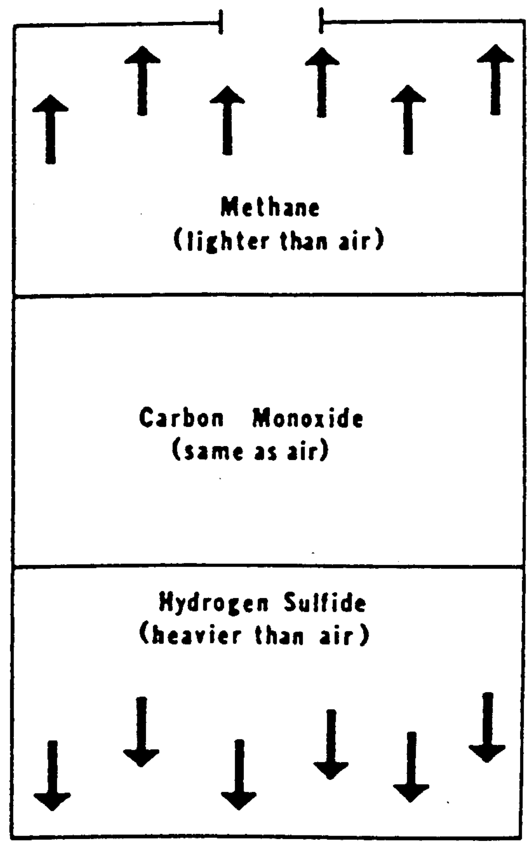
6.8.7 Atmospheric Testing of Permit-Required Confined Spaces

All permit-required confined spaces must be considered LIFE THREATENING before entry until proven safe. Air monitoring shall be performed before removing the cover, if practical. Some lids have openings through which a probe may be inserted. If not, the lid must be carefully removed using appropriate tools, and the atmosphere shall be tested before entry.

The principal atmospheric tests will be for oxygen deficiency and explosive and toxic gases. Combination meters are available that will give an indication of the percentage of oxygen and the percent of the lower explosive limit of the tested atmosphere. Additionally, the atmosphere shall be tested for toxic gases such as hydrogen sulfide, carbon monoxide, methane, carbon dioxide, or other suspected gases or vapors.

It is important to understand that some gases or vapors are heavier than air and will settle to the bottom of the space, whereas some gases are lighter than air and will be found around the top of the confined space as shown in Figure 6.1.

Test all areas (top, middle, bottom) of a space. Entry will be allowed only when the following atmospheric conditions are met:.



Atmospheric Testing: From the Outside, Top to Bottom

- The oxygen concentration in the confined space is greater than 19.5 percent and less than 23.5 percent by volume.
- The presence of flammable gases or vapors is less than 10 percent of the lower flammable limit.
- Potential toxic gases or vapor are present at concentrations below the OSHA permissible exposure limit (e.g., less than 10 ppm for hydrogen sulfide).

If atmospheric readings do not comply with acceptable entry parameters, then ventilation of the space is required. A blower for positive displacement of the atmosphere is often used. Allow sufficient time for the blower to displace three times the volume of the space. Next, retest the space to verify that acceptable concentrations have been met before any entry to the space is made. The blower shall remain in operation throughout occupancy of the space.

When using gasoline- or diesel-powered blowers, ensure that the exhaust gas from the engine is not drawn into the space by the blower. If a hazardous atmosphere persists in spite of ventilation, it will be necessary for the employee to use proper respiratory protection equipment. A positive-pressure self-contained breathing apparatus or positive-pressure airline respirator with a 5-minute escape tank is frequently used.

Personnel working in a permit-confined space must be equipped with a continuous atmospheric monitoring device. This is true even if the atmosphere was found to be safe initially, since conditions can change. Equipment used for continuous monitoring of the atmosphere shall be explosion-proof and equipped with an audible alarm that will alert employees when a hazardous condition develops.

An employee's well-being depends on the proper functioning of safety equipment. Careful, regular maintenance of the monitoring equipment is essential. All monitoring instruments must be calibrated prior to use and records of calibration maintained. The Figure 6.1 Atmospheric Testing from outside, top to bottom limitations and possible sources of error for each instrument must be understood by the operator.

6.8.8 Isolating the Permit Space

Whenever entry into a permit-confined space is necessary, the space must be isolated from all other systems. This is to insure that injury does not occur.

Blanks must be used to physically isolate all lines into the confined space. Shut-off valves or pipelines to the space must be locked in the closed position and tagged for identification. Pumps and compressors connected to these pipelines must be locked out and tagged to prevent accidental activation. In continuous systems, where complete isolation is not possible (e.g., sewers), specific written safety procedures should be developed and used.

Electrical isolation of the confined space is necessary to prevent accidental activation of moving parts that would be hazardous to the worker. Circuit breakers or disconnects should be locked out and tagged in the off position with a key-type padlock. The only key is to remain with the person working inside who locked the breaker. If more than one person is inside the space, each person should place his or her own lock on the circuit breaker.

Mechanical isolation of moving parts can be achieved by disconnecting linkages or removing drive belts or chains. Equipment with moving mechanical parts should also be blocked in such a manner that there can be no accidental rotation. Remember, lives are at stake, and all of these steps are equally important. All lock out and tag out procedures must conform to OSHA standards (see CFR 1910.147).

6.8.9 Responsibilities and Duties of Personnel Conducting Permit-Required Confined Space Operations

As stated in Paragraph 6.8.4, the plant's permit-required confined space entry program should designate personnel who have active roles in the program. Every permit-required confined space operation requires authorized entrant(s), an attendant, an entry supervisor, and access to rescue services.

Any person entering a permit-required confined space must know the potential hazards, including the signs or symptoms and consequences of exposure and the required safety procedures. Entrants must be familiar with the proper use of equipment and should be in constant communication with the outside attendant. When an entrant recognizes signs or symptoms of exposure to hazardous substance or detects a prohibited condition, the entrant must inform the attendant of the problem and initiate evacuation.

The attendant remains outside the permit space during the entire operation and is responsible for maintaining an accurate count of entrants in the confined space. The attendant should communicate with entrants as necessary to monitor status. Similarly to entrants, the attendant must know potential hazards during entry, including signs, symptoms, and behavioral effects of exposure to hazardous substances. The attendant monitors activities inside and outside the space to determine if it is safe for the entrants to remain. The attendant is required to order an immediate evacuation of the space when one of the following conditions occur:

- A prohibited condition is detected in the space.
- The attendant detects the behavioral effects of hazard exposure in an entrant.
- The attendant detects a situation outside the space that could endanger the entrants.

In the event of an emergency requiring the rescue of an entrant, the attendant is only permitted to perform non-entry rescue (i.e., extracting personnel by use of retrieval systems) or to summon rescue services.

The entry supervisor is the individual responsible for the development of the permit and has overall accountability for the safety of the operation. The entry supervisor checks permit entries verifying that all tests specified have been conducted and that all procedures and equipment are in place prior to entry. Additionally, the entry supervisor ensures rescue services is readily accessible.

The nature of work in confined spaces makes emergencies a continual possibility, no matter how infrequently they actually occur. Emergencies occur quickly and unexpectantly and require immediate response. In an emergency, rescue personnel would either enter a permit space to remove entrants or would remain outside and pull out entrants by use of retrieval lines. The plant may either establish an in-house rescue team or make arrangements for off-site services (i.e., fire department). If off-site emergency rescue services are to be used, the response time to the site must be within 4 minutes.

6.8.10 Training for Permit-Required Confined Space Work

Anyone entering a permit space must recognize and understand the potential hazards to health and safety associated with the operation. Personnel involved in permit space activities must be thoroughly familiar with the plant's permit-required confined space program and must receive training. The objectives of the confined space training program are:

- To make workers aware of the potential hazards they may encounter.
- To provide the knowledge and skills necessary to perform the work with minimal risk to worker health and safety.
- To ensure that workers can safely avoid or escape from emergencies.

The level of training should be consistent with the worker's job function and responsibilities. The training program must involve both classroom instruction and hands-on practice. Hands-on instruction should consist of entry and rescue drills. Employees must demonstrate proficiency in the knowledge and skills necessary for safe entry and response (proficiency may be demonstrated through oral or written examination or evaluation of field simulations).

Training is required before the employee is assigned to a confined space operation and when the employee's assigned duties change (e.g., when responsibilities change from entrant to attendant). Members of the in-house rescue team must practice confined space rescues annually. This training should consist of simulated rescues in which the team removes a mannequin or people from actual permit-required spaces.

CHAPTER 7
MAINTENANCE

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MAINTENANCE

7.1 INTRODUCTION

The term "maintenance" has many definitions, but in an engineering sense, total maintenance may be defined as the art of keeping plant equipment, structures, and other related facilities in a suitable condition to perform the services for which they were intended. "Preventive maintenance" is defined as the activities required to prevent process shutdown, reduce the wear on all equipment, and extend the life of equipment and structures. "Corrective maintenance" is defined as the activities required to repair malfunctioning or inoperable equipment.

To ensure the continuous trouble free operation of the MacDill AFB wastewater treatment plant, an effective "total maintenance" program is required. A total maintenance program is a schedule that incorporates preventive maintenance and corrective maintenance activities. By regular inspection and maintenance of each piece of equipment and keeping accurate records of performed maintenance, problems can be anticipated and usually avoided, thus reducing events of equipment failure and unscheduled shutdowns.

Planning and implementing an effective preventive maintenance program are essential in producing quality effluent on a continuous basis. In this chapter, a recommended approach to plant maintenance is discussed in general terms. A preventive maintenance and lubrication schedule for servicing of the plant's equipment is provided. The schedule was compiled from equipment manufacturers' manuals and existing WWTP maintenance procedures. Frequency and type of required maintenance reflect these information sources. A manual record-keeping system for maintenance is also described. Forms for this record-keeping system are provided in Appendix B.

7.2 PREVENTIVE MAINTENANCE

Preventive maintenance may be defined as the art of preventing equipment failure by establishing a system of regular inspections and scheduled maintenance based on equipment repair history to detect trouble spots before they become the cause of major problems. Preventive maintenance is the key element in the plan for management of the maintenance function.

Typically, a preventive maintenance (PM) program includes the following:

1. Equipment inspection.
2. Lubrication.
3. Minor adjustments.
4. Housekeeping, keeping equipment clean.
5. Equipment rotation.
6. Record keeping and scheduling.

The following cite just a few advantages of an effective PM program:

1. Fewer Failures. A timely PM program uncovers problems before they become serious enough to cause equipment failure. As a result, routine adjustments and minor repairs take the place of failures.
2. More Planned Work. The timeliness of PM inspections uncovers those major jobs that require preplanning.
3. Fewer Emergencies. An effective PM program has every employee on the alert for those things that cause problems. As a result, fewer problems escape detection to generate an emergency situation.
4. Reduced Overtime. One of the largest contributing factors to overtime is the need to perform emergency repairs.
5. Extended Equipment Life. PM means timely adjustments, better lubrication, etc. Equipment treated in such a way rewards its users by lasting longer and, thus, is less costly to the system users.

7.2.1 Equipment Inspection

The most critical part of the PM program is the "Operations and Maintenance Routine Check." This is the portion of the program that generates the advance information on the status of the equipment. This information provides the lead time that permits maintenance to be planned. The PM program then becomes "detection oriented" with the principal aim of uncovering problems before they become serious. Checksheets for the MacDill WWTP are included in Chapter 8 as part of the Standard Operations Procedures.

In the interest of making the best use of time and due to the fact that these two functions are inseparable, "operating conditions" and "maintenance conditions" are examined at the same time. Every item on a plant check list should be examined at least at the frequency indicated. It is good operating procedure to conduct this inspection at the beginning of a shift. Deficiencies found should be noted on a special "Trouble Report" or other approved form for requesting maintenance.

7.2.2 Lubrication

Proper lubrication is essential to keeping treatment plant equipment operating. Lubricants are applied in a number of ways ranging from a hand-operated oil can to complicated automated systems. The success of any lubrication system is dependent upon the lubricator's attention to oil levels, applying the proper lubricant in the proper amount at the proper time, and on regular inspection of lubrication systems.

The basic rule of thumb for proper lubrication is that the right lubricant must be applied at the right place, at the right time, and in the right amount.

The proper lubricant is specified by the equipment manufacturer. Refer to the operating manual supplied to be sure you are using the proper lubricant.

7.2.3 Minor Adjustments

An ounce of prevention is worth a pound of cure. Both operation and maintenance people must be constantly on the alert for minor problems and make the necessary repairs before major problems develop. This includes such things as:

1. Excessive leakage on packing.
2. Minor oil leaks.
3. Minor leaks on valves and fittings.
4. Belt adjustments.

Excessive leakage on packing, if not adjusted immediately, will ruin the packing and cause damage to shaft sleeves and shafts (some leakage around water lube packing is necessary). Minor leaks, if not stopped immediately, will soon develop into major leaks and major problems. V-belts, if not adjusted properly, will cause rapid wear of belts and possible breakdown of equipment. These are the types of items that the operator must be very aware of when making routine checks of the plant.

7.2.4 Housekeeping

Maintenance of a clean, safe, and orderly working environment is essential to efficient and effective plant operations. Plant housekeeping is the responsibility of all plant employees and must be performed on a continuous basis. Certain housekeeping functions can and should be performed by each employee as part of the normal daily work routine. These include:

1. Replacement of all tools and equipment to their normal storage locations.
2. Removal of trash, rocks, and other debris from work areas and walkways.
3. Proper storage of all cleaning solvents and other small chemical containers.
4. Proper disposal of all dirty or oily rags.
5. Thorough cleaning of an area once work in that area has been completed (may include washdown).
6. Prompt cleanup of all spills.
7. Reporting of any dirty, broken, or nonfunctional equipment.

7.2.5 Tools and Tool Room Control

An important aspect of preventive maintenance, as well as corrective maintenance, is the availability of proper tools to do the job. Tools should be stored in specific locations at the maintenance shop (Building 1205). Specialty tools and delicate instruments should be stored in restricted areas, and use of them should be carefully controlled by the plant superintendent or assistant superintendent.

7.3 PLANT MAINTENANCE PROGRAM

Preventive maintenance is scheduled for major operating equipment at the WWTP, lift stations, and the two package treatment plants. Greasing (where not supplied by the automatic greasers) and oil changes are scheduled for blowers and gear reducers on a monthly basis. The maintenance management system called the Recurring Work Program (RWP) is utilized for the two swimming pools only, for which the WWTP maintenance crew is responsible. A maintenance history of each item that is performed is recorded in a log book, although no record is kept on each item individually, nor are equipment record cards used. Spare parts are kept on hand but not inventoried. Long lead-time and critical parts, such as submersible pumps and 7.5-HP and 11.3-HP motors for the major lift stations, are kept on hand in addition to smaller submersible pumps, drive belts, valves, etc. Emergency requisitions can be processed on items within several hours time, or less.

Local shops are used for motor rewinding. Base maintenance vehicles, such as an electric line truck or crane, are available for removal of the larger pumps, motors or equipment.

7.4 MAINTENANCE RECORD KEEPING AND SCHEDULING

This section outlines additional maintenance record keeping to ensure continued efficient operation of the MacDill AFB wastewater treatment plant. This maintenance data and record keeping are essential to a total maintenance program. These forms which are included in Appendix B can be copied and stored in a loose-leaf binder for easy access and use.

7.4.1 Equipment Data

Data cards should be prepared for each item of equipment in the system. Format examples of data cards for pumps, motors, and other mechanical equipment are presented in Figures B.1, B.2, and B.3. Any convenient indexing system may be used, but it is suggested that all mechanical equipment be filed according to the ID number assigned to each piece of equipment.

Upon completion of all equipment data record forms, they should be filed according to system designation and in alphabetical order. These forms will save many hours in the future and will preserve nameplate data on equipment which is subject to obliteration, abrasion, and painting.

7.4.2 Spare Parts Records

A number of spare parts should always be carried in stock to eliminate or reduce the possibility of an equipment item being out of service for an extended period of time due to a lack of parts. The type and number of spare parts to be maintained should be determined based upon the likelihood of failure, the shelf life of the part, the critical nature of the item, local availability of the part, and the time required to get the part when it is needed, if it is not stocked. The manufacturers' O&M literature contains lists of recommended spare parts.

Figure B.4 is a suggested form to serve as a means of maintaining a record of spare parts as they are placed on order, to record their receipt and issue, and to inventory the parts in stock.

7.4.3 Inventory Control

In addition to spare parts records for all plant equipment, a file system should also be used to maintain an inventory of expendable supplies, lubricants, and other miscellaneous items. Figure B.5 presents a sample inventory card to be used for this purpose.

7.5 PREVENTIVE MAINTENANCE SCHEDULE

This section presents the routine preventive maintenance (PM) and lubrication schedule for the equipment included in the MacDill AFB wastewater treatment plant. Schedules for the seven major lift stations have also been included. These schedules were derived from maintenance instructions contained in vendor literature, when available. Equipment manuals should be consulted before performing any preventive or corrective maintenance. Vendor literature is contained in three-ring binders located both at the WWTP Main Control Building and at the Maintenance Shop (Building 1205). The PM schedules are presented in Tables 7.1 through 7.25.

7.5.1 Safety Precautions

Before any maintenance or inspection is done on the equipment in the treatment system, it is of utmost important that several basic safety precautions be followed:

a) Notify supervisory personnel of intention.

b) Disconnect power to any applicable equipment, lock it out, and tag it. OSHA requires formal lock out procedures be practiced for mechanical and electrical work on all electrically driven equipment.

c) Put on the proper protective gear for the material expected in the equipment.

d) Check for power at the local hand switch to ensure that power is off, and test atmosphere for hazardous vapor levels if entering a confined space.

e) Use tools fitted to the job, such as non-sparking for an explosive atmosphere.

f) Do not enter any tank or structure considered a confined space unless all appropriate safety procedures are followed.

g) Relieve the pressure, and drain all piping, valves, and pumps before disassembly.

h) Immediately clean up spillage from nearby equipment or structures.

i) Reassemble equipment per manufacturer instructions.

j) Clear all personnel from immediate area of work before placing equipment back in service.

TABLE 7.1

Lift Station No. 21
Preventive Maintenance Schedule

Weekly

1. Conduct operational check.
2. Check for corrosion on equipment and throughout lift station. If corrosion does exist, put on maintenance schedule.
3. Check for leaks on all piping. Put leaks on maintenance schedule.
4. Visually check operation of pumps by observing wet well drawdown.
5. Tighten or replace missing or loose nuts, bolts, or screws.
6. Check operation of float system.
7. Clean area.
8. Check audible and visual alarms for operation.
9. Check pump alternation for operation.
10. Visually inspect power pump cables for any signs of abrasion or damage that might affect the integrity of the outer jacketing.

Monthly

1. Check electric panels for loose or frayed wiring. Tighten or replace as required. Check lights on control panel, replace as required.
2. Clean inside of control panel.

Semiannually

1. Lift pumps and check motor, pump body and impeller for corrosion and wear.

Annually

1. Inspect motor and seal chambers for oil level and contamination. Drain, flush and refill the seal chamber with new oil as required.

TABLE 7.2

Lift Station No. 22
Preventive Maintenance Schedule

Daily

1. Conduct visual check of lift station and equipment.
2. Clean bar screen.

Weekly

1. Conduct operational check.
2. Check for corrosion on equipment and throughout lift station. If corrosion does exist, put on maintenance schedule.
3. Check for leaks on all piping. Put leaks on maintenance schedule.
4. Visually check operation of pumps by observing wet well drawdown.
5. Tighten or replace missing or loose nuts, bolts, or screws.
6. Check operation of float system.
7. Clean area.
8. Check audible and visual alarms for operation.
9. Check pump alternation for operation.
10. Visually inspect power pump cables for any signs of abrasion or damage that might affect the integrity of the outer jacketing.

Monthly

1. Check electric panels for loose or frayed wiring. Tighten or replace as required. Check lights on control panel, replace as required.
2. Clean inside of control panel.

Semiannually

1. Lift pumps and check motor, pump body and impeller for corrosion and wear.

Annually

1. Inspect motor and seal chambers for oil level and contamination. Drain, flush and refill the seal chamber with new oil as required.

TABLE 7.3

**Lift Station No. 62
Preventive Maintenance Schedule**

Weekly

1. Conduct operational check.
2. Check for corrosion on equipment and throughout lift station. If corrosion does exist, put on maintenance schedule.
3. Check for leaks on all piping. Put leaks on maintenance schedule.
4. Visually check operation of pumps by observing wet well drawdown.
5. Tighten or replace missing or loose nuts, bolts, or screws.
6. Check operation of float system.
7. Clean area.
8. Check visual alarm for operation.
9. Check pump alternation for operation.
10. Visually inspect power pump cables for any signs of abrasion or damage that might affect the integrity of the outer jacketing.

Monthly

1. Check electric panels for loose or frayed wiring. Tighten or replace as required. Check lights on control panel, replace as required.
2. Clean inside of control panel.

Semiannually

1. Lift pumps and check motor, pump body and impeller for corrosion and wear.

Annually

1. Inspect motor and seal chambers for oil level and contamination. Drain, flush and refill the seal chamber with new oil as required.

TABLE 7.4

Lift Station No. 633
Preventive Maintenance Schedule

Daily

1. Conduct visual check of lift station and equipment.
2. Clean bar screen.

Weekly

1. Conduct operational check.
2. Check for corrosion on equipment and throughout lift station. If corrosion does exist, put on maintenance schedule.
3. Check for leaks on all piping. Put leaks on maintenance schedule.
4. Visually check operation of pumps by observing wet well drawdown.
5. Tighten or replace missing or loose nuts, bolts, or screws.
6. Check operation of float system.
7. Clean area.
8. Check audible and visual alarms for operation.
9. Check pump alternation for operation.
10. Visually inspect power pump cables for any signs of abrasion or damage that might affect the integrity of the outer jacketing.

Monthly

1. Check electric panels for loose or frayed wiring. Tighten or replace as required. Check lights on control panel, replace as required.
2. Clean inside of control panel.

Semiannually

1. Lift pumps and check motor, pump body and impeller for corrosion and wear.

Annually

1. Inspect motor and seal chambers for oil level and contamination. Drain, flush and refill the seal chamber with new oil as required.

TABLE 7.5

Lift Station No. 705
Preventive Maintenance Schedule

Weekly

1. Conduct operational check.
2. Check for corrosion on equipment and throughout lift station. If corrosion does exist, put on maintenance schedule.
3. Check for leaks on all piping. Put leaks on maintenance schedule.
4. Visually check operation of pumps by observing wet well drawdown.
5. Tighten or replace missing or loose nuts, bolts, or screws.
6. Check operation of float system.
7. Clean area.
8. Check audible and visual alarms for operation.
9. Check pump alternation for operation.
10. Visually inspect power pump cables for any signs of abrasion or damage that might affect the integrity of the outer jacketing.

Monthly

1. Check electric panels for loose or frayed wiring. Tighten or replace as required. Check lights on control panel, replace as required.
2. Clean inside of control panel.

Semiannually

1. Lift pumps and check motor, pump body and impeller for corrosion and wear.

Annually

1. Inspect motor and seal chambers for oil level and contamination. Drain, flush and refill the seal chamber with new oil as required.

TABLE 7.6

Lift Station No. 706
Preventive Maintenance Schedule

Weekly

1. Conduct operational check.
2. Check for corrosion on equipment and throughout lift station. If corrosion does exist, put on maintenance schedule.
3. Check for leaks on all piping. Put leaks on maintenance schedule.
4. Visually check operation of pumps by observing wet well drawdown.
5. Tighten or replace missing or loose nuts, bolts, or screws.
6. Check operation of float system.
7. Clean area.
8. Check audible and visual alarms for operation.
9. Check pump alternation for operation.
10. Visually inspect power pump cables for any signs of abrasion or damage that might affect the integrity of the outer jacketing.

Monthly

1. Check electric panels for loose or frayed wiring. Tighten or replace as required. Check lights on control panel, replace as required.
2. Clean inside of control panel.

Semiannually

1. Lift pumps and check motor, pump body and impeller for corrosion and wear.

Annually

1. Inspect motor and seal chambers for oil level and contamination. Drain, flush and refill the seal chamber with new oil as required.

TABLE 7.7

Lift Station No. 718
Preventive Maintenance Schedule

Weekly

1. Conduct operational check.
2. Check for corrosion on equipment and throughout lift station. If corrosion does exist, put on maintenance schedule.
3. Check for leaks on all piping. Put leaks on maintenance schedule.
4. Visually check operation of pumps by observing wet well drawdown.
5. Tighten or replace missing or loose nuts, bolts, or screws.
6. Check operation of float system.
7. Clean area.
8. Check audible and visual alarms for operation.
9. Check pump alternation for operation.
10. Visually inspect power pump cables for any signs of abrasion or damage that might affect the integrity of the outer jacketing.

Monthly

1. Check electric panels for loose or frayed wiring. Tighten or replace as required. Check lights on control panel, replace as required.
2. Clean inside of control panel.

Semiannually

1. Lift pumps and check motor, pump body and impeller for corrosion and wear.

Annually

1. Inspect motor and seal chambers for oil level and contamination. Drain, flush and refill the seal chamber with new oil as required.

TABLE 7.8

Mechanical Bar Screen
Preventive Maintenance Schedule

Daily
1. Make operational check. Observe screen in operation.
2. Check for water leaks and any unusual accumulations of debris on or around screen.
3. Check for hydraulic leaks and any unusual noises, vibration or abnormal operating temperatures of bearings and motors.
4. Clean up area as required.
5. Observe level up-stream and down-stream of screen.
6. Observe condition of bars on screen for damage.
Weekly
1. Inspect filter screen for damaged or bent elements and repair or replace as required.
2. Inspect spray wash headers and flush debris from outlet slots as necessary.
Monthly
1. Grease drive shaft per manufacturers' specifications.
2. Tighten all bolts as needed.
Semiannually
1. Grease motors per manufacturers' specifications.

TABLE 7.9

Parshall Flumes (Influent and RAS)
Preventive Maintenance Schedule

Daily
1. Make operational check.
2. Inspect flume for debris. Remove if present.
3. Check operation of flow meter. Check that float is riding correctly on fluid surface in stilling well.
Monthly
1. Check accuracy of meter by checking head in stilling well manually. Determine flow from rating curve provided by vendor, compare with chart flow.

TABLE 7.10

Grit Collector and Screw Classifier Preventive Maintenance Schedule

Daily

1. Observe equipment for proper operation. Check for vibration, leaks, excessive temperatures, and unusual noises in motors, drives, gear boxes and pumps.
2. Check for corrosion on equipment. Clean and paint as required.
3. Tighten or replace loose bolts, nuts, or screws.
4. Check pinch valve and gauge at gearhead.
5. Check level in classifier lubricator.
6. Clean up area.

Weekly

1. Check oil level in gear boxes.
2. Grease gearhead.

Monthly

1. Check for grease flow from the lubrication unit on the classifier bottom bearing as per manufacturer's instructions.
2. Check grit pump unit.
3. Check vacuum prime system.
4. Check and adjust settling chamber drive belt.
5. Drain condensation from gear boxes/drive units.
6. Check controls, fuses, overloads, relays and timers for proper operation.

Quarterly

1. Grease drive units (grease lubricated bearings only).

Semi-Annually

1. Change oil in gear boxes and speed reducers as per manufacturer's instructions.

Annually

1. Grease all motors as per manufacturers' specifications.
2. Drain chamber and inspect impeller, impeller blades, and all equipment including chamber walls for wear, corrosion, and deterioration. Remove any rags or stringy materials which may have collected on the impeller and impeller blades.
3. Check condition of all bearings.

TABLE 7.11

**Equalization Basin Blowers
Preventive Maintenance Schedule**

Daily
1. Check motor and blower for excessive heat, noise, or vibration.
2. Check oil level. Add oil to maintain required level.
3. Check grease vents on blower. Vents must be open at all times.
4. Clean blowers and motors to prevent buildup of grease and oil.
5. Clean up area as required.
Every 500 Hours
1. Grease drive end bearings of blowers with recommended lubricants.
2. Check V-belt tension and adjust if necessary.
Every 1500 Hours
1. Drain oil from blower, flush and refill with recommended oil.
Annually
1. Grease motors per manufacturers' specifications.

TABLE 7.12

Main Pump Station
Preventive Maintenance Schedule

Weekly
1. Conduct operational check.
2. Clean exterior of equipment.
3. Check for corrosion on equipment and throughout lift station. If corrosion does exist, put on maintenance schedule.
4. Check for leaks on all pumps and piping. Put leaks on maintenance schedule.
5. Check running equipment for vibration, noise, or excessive heat. If excessive vibration is detected, check alignment. Observe vibration of long shafts.
6. Tighten or replace missing or loose nuts, bolts, or screws.
7. Check operation of float system.
8. Clean area.
Monthly
1. Lubricate pumps per manufacturers' specifications.
2. Check electric panels for loose or frayed wiring and tighten or replace as required. Check lights on control panel and replace as required.
3. Clean inside of control panel.
Semi-Annually
1. Check stuffing box gland and observe stuffing box for excessive leakage; repack if necessary.
2. Clean and oil the gland nuts and studs.
Annually
1. Grease motors per manufacturers' specifications.
2. Clean and relubricate pump bearings per manufacturers' specifications.

TABLE 7.13

Aeration Tanks
Preventive Maintenance Schedule

Daily
1. Observe aeration tank surface pattern; localized turbulence may indicate damaged piping or diffusers.
Annually
1. Drain and clean tanks, checking for cracks, leaks, deterioration, and drain valve conditions.   2. Paint all handrails and equipment as required.

TABLE 7.14

Aeration Basin Blowers
Preventive Maintenance Schedule

Daily
1. Check motor and blower for excessive heat, noise, or vibration.
2. Check oil level. Add oil to maintain required level.
3. Check grease vents on blower. Vents must be open at all times.
4. Clean blowers and motors to prevent buildup of grease and oil.
5. Clean up area as required.
Every 500 Hours
1. Grease drive end bearings of blowers with recommended lubricants.
2. Check V-belt tension and adjust or replace if necessary.
Every 1500 Hours
1. Drain oil from blower, flush and refill with recommended oil.
Annually
1. Grease motors per manufacturers' specifications.

TABLE 7.15

Final Clarifiers
Preventive Maintenance Schedule

Daily

1. Visually inspect equipment for proper operation.
2. Observe operation of drive units. Look for accumulation of dirt, oil, or grease. Check for unusual noises, vibration, or heat. Clean or repair as required.
3. Observe surface skimmer. Observe for proper action on scum beach and reentry into tank. Observe scum box for plugging.
4. Check weir levels. Clean weirs as required.

Monthly

1. Check oil sump levels in gear boxes. Fill as necessary.

Annually

1. Drain clarifiers. Clean and inspect all submerged equipment.
2. Check scraper arms for clearance or damage.
3. Repair and paint as necessary.
4. Check torque overload switches.

TABLE 7.16

Skimmings Pump Station
Preventive Maintenance Schedule

Weekly

1. Conduct operational check.
2. Visually check operation of pumps by observing wet well drawdown.
3. Tighten or replace missing or loose nuts, bolts, or screws.
4. Check operation of float system.
5. Check pump alternation for operation.
6. Visually inspect power pump cables for any signs of abrasion or damage that might affect the integrity of the outer jacketing.

Monthly

1. Check electric panels for loose or frayed wiring. Tighten or replace as required. Check lights on control panel, replace as required.
2. Clean inside of control panel.

Semiannually

1. Lift pumps and check motor, pump body and impeller for corrosion and wear.

Annually

1. Inspect motor and seal chambers for oil level and contamination. Drain, flush and refill the seal chamber with new oil as required.

TABLE 7.17

Waste Sludge Pump Station
Preventive Maintenance Schedule

Daily

1. Check motors and pumps for unusual noise, heat or vibration.
2. Check all nuts and cap screws for tightness.
3. Check suction and discharge pressure gauges while pump is operating.

Monthly

1. Check coupling wear and alignment.
2. Check belt tension and adjust if necessary.
3. Grease pedestal bearings per manufacturers' specifications.

Annually

1. Inspect upper surface of trunnions for any signs of cracking or flex failure. Replace trunnions immediately if any deterioration is noticed.
2. Grease motors per manufacturers' specifications.

TABLE 7.18

Tertiary Filters
Preventative Maintenance Schedule

Weekly
1. Check all air lines for leaks.
2. Check backwash pump while running for unusual leaks, noise, heat or vibrations.
3. Check backwash holding pump for unusual leaks, noise, heat or vibration during operation.
4. Visually inspect filter media surface for signs of abnormal conditions.
5. Check air compressor for proper operation.
6. Check air compressor tank pressure.
Monthly
1. Grease pump bearings per manufacturers' specifications.
Annually
1. Grease motors per manufacturers' specifications.

TABLE 7.19

Chlorinator
Preventive Maintenance Schedule

Daily

1. Check operation of chlorinator at least once per shift. Follow all safety procedures.
2. Clean rotometer as required.
3. Check gas detector for proper operation.
4. Be sure gas cylinders are chained in place.
5. Check vacuum. If vacuum is low, clean y-strainer in vacuum supply line. Clean nozzle and throat in ejector.
6. Clean area as required. Watch for corrosion and paint as required.
7. Check exhaust fan for proper operation.

Every 3 Months

1. Conduct a performance check on all elements of chlorinator systems. Follow all safety procedures. Use troubleshooting guides in equipment manual.

TABLE 7.20

**Chlorine Contact Tanks
Preventive Maintenance Schedule**

Annually
1. Drain and clean tanks. Check for cracks, leaks, and deterioration.

TABLE 7.21

Effluent Pump Station
Preventive Maintenance Schedule

Daily
1. Conduct operational check. Check for any unusual accumulations and unusual noises, vibration, or abnormal operating temperatures of bearings and motors.
Weekly
1. Check oil level in motors with sight gauge in motor base. Replenish as necessary using a premium quality turbine oil as recommended in manufacturers literature. 2. Check motor for loose connections and mounting hardware. Tighten as required. 3. Check pumps for loose bolts or piping. Remove dirt and corrosion and treat as required to prevent recurrence. 4. Check the pump packing. Verify that a small trickle of water is leaking through the top of the gland, and adjust the gland nuts as necessary.
Annually
1. Change oil in lubricated motor bearings. 2. Repack the pump packing box. Check shaft alignment and surface finish.

TABLE 7.22

**Anaerobic Digesters
Preventive Maintenance Schedule**

Weekly
1. Check operation of submersible mixer.
Annually
1. Drain and clean tanks. Check for cracks or signs of deterioration in tanks.

TABLE 7.23

Digested Sludge Pumps
Preventive Maintenance Schedule

Daily
1. Check motor and pumps for unusual noise, heat or vibration. 2. Check all nuts and cap screws for tightness. 3. Check suction and discharge pressure gauges while pump is operating.
Monthly
1. Check coupling wear and alignment. 2. Check belt tension and adjust if necessary. 3. Grease pedestal bearings per manufacturers' specifications.
Annually
1. Inspect upper surface of trunnions for any signs of cracking or flex failure. Replace trunnions immediately if any deterioration is noticed. 2. Grease motor bearings per manufacturers' specifications.

TABLE 7.24

Plant Gates, Valves, and Sluice Gates
Preventive Maintenance Schedule

Annually
1. Operate gates and valves in the plant and perform lubrication as recommended by manufacturer.

TABLE 7.25

Effluent Sprayfields
Preventive Maintenance Schedule

Daily
1. Observe sprayheads during operation to determine plugging problems or low delivery pressure.
Weekly
1. Check operation of pumps and motors for unusual noise, heat or vibration. 2. Check sprayfields for mowing requirements; schedule mowing if necessary.
Quarterly
1. Apply grease to sprayfield pump bearings per manufacturers' specifications.
Annually
1. Grease motors per manufacturers' specifications.

CHAPTER 8
STANDARD OPERATING PROCEDURES

CHAPTER 8
STANDARD OPERATING PROCEDURES

8.1 INTRODUCTION

This chapter presents standard operating procedures (SOPs) for the MacDill AFB wastewater treatment plant. The procedures are presented in a tabular and checklist format so they can be removed, copied, and used in the field during operations.

The procedures should be read and understood before initiating operations of the various treatment systems. Also, daily O&M check sheets should be utilized for routine plant and lift station equipment monitoring. Vendor and manufacturer's literature should also be consulted as supplements to these procedures. Additionally, the preventive maintenance and laboratory sampling and analytical schedules contained in Chapters 7 and 4, respectively, should be consulted as needed. These SOPs are designed to aid the operator in the consistent and safe operation of the MacDill WWTP. They also can serve as documents to use in training new operators.

No operating procedures can be fully accurate without the input of the operating staff. Thus, when reviewing or using these procedures, the operations personnel should note any conflicts, discrepancies, or possible unsafe situations which are inherent in them. Corrections can then be instituted to insure that the procedures accurately describe the proper operating steps.

Figures 8.1 through 8.10 are provided to illustrate equipment, valve and gate locations for reference when using these procedures.

Figure 8.1

MACDILL AFB WWTP HEADWORKS VALVE AND EQUIPMENT DIAGRAM

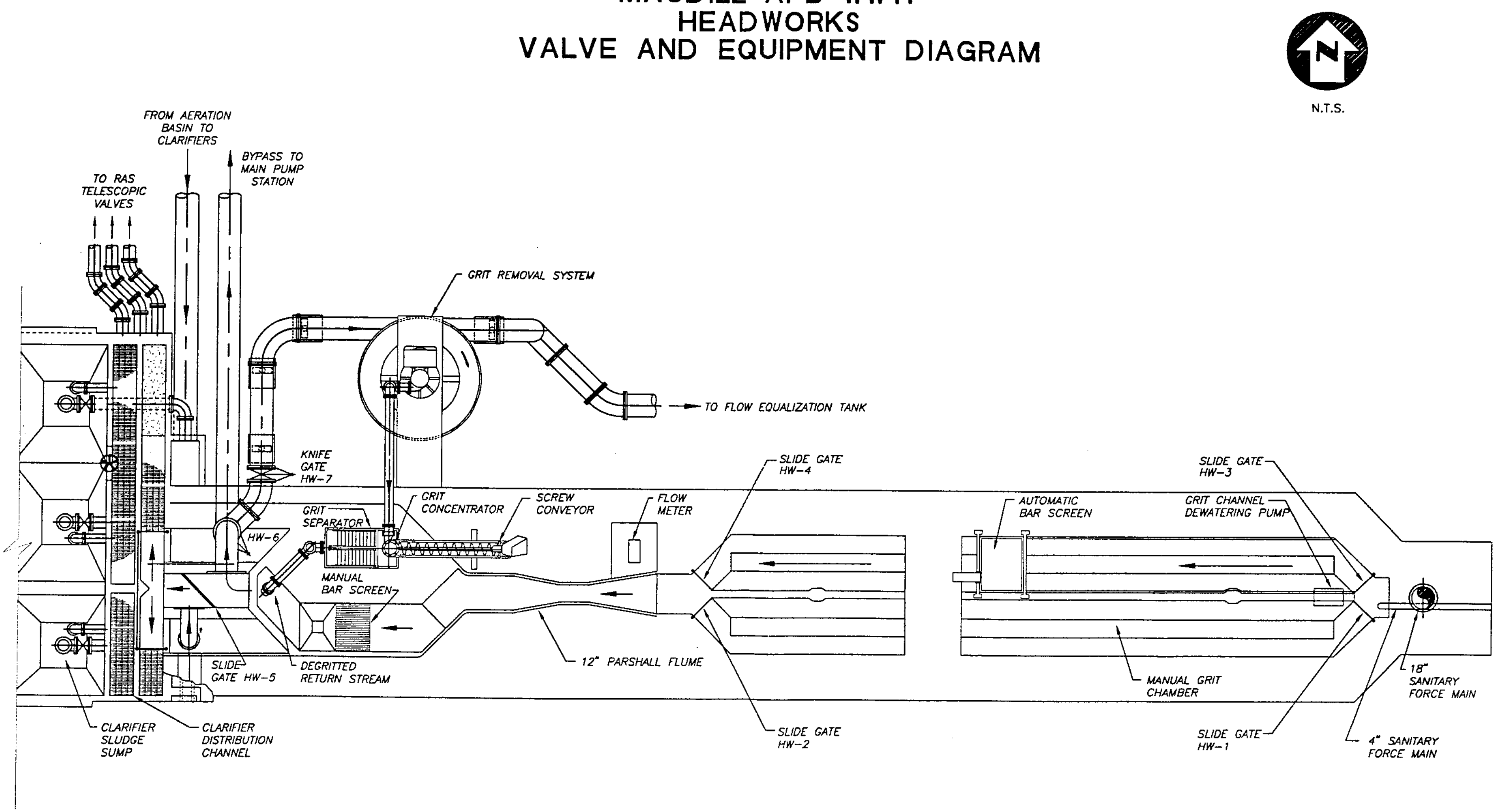

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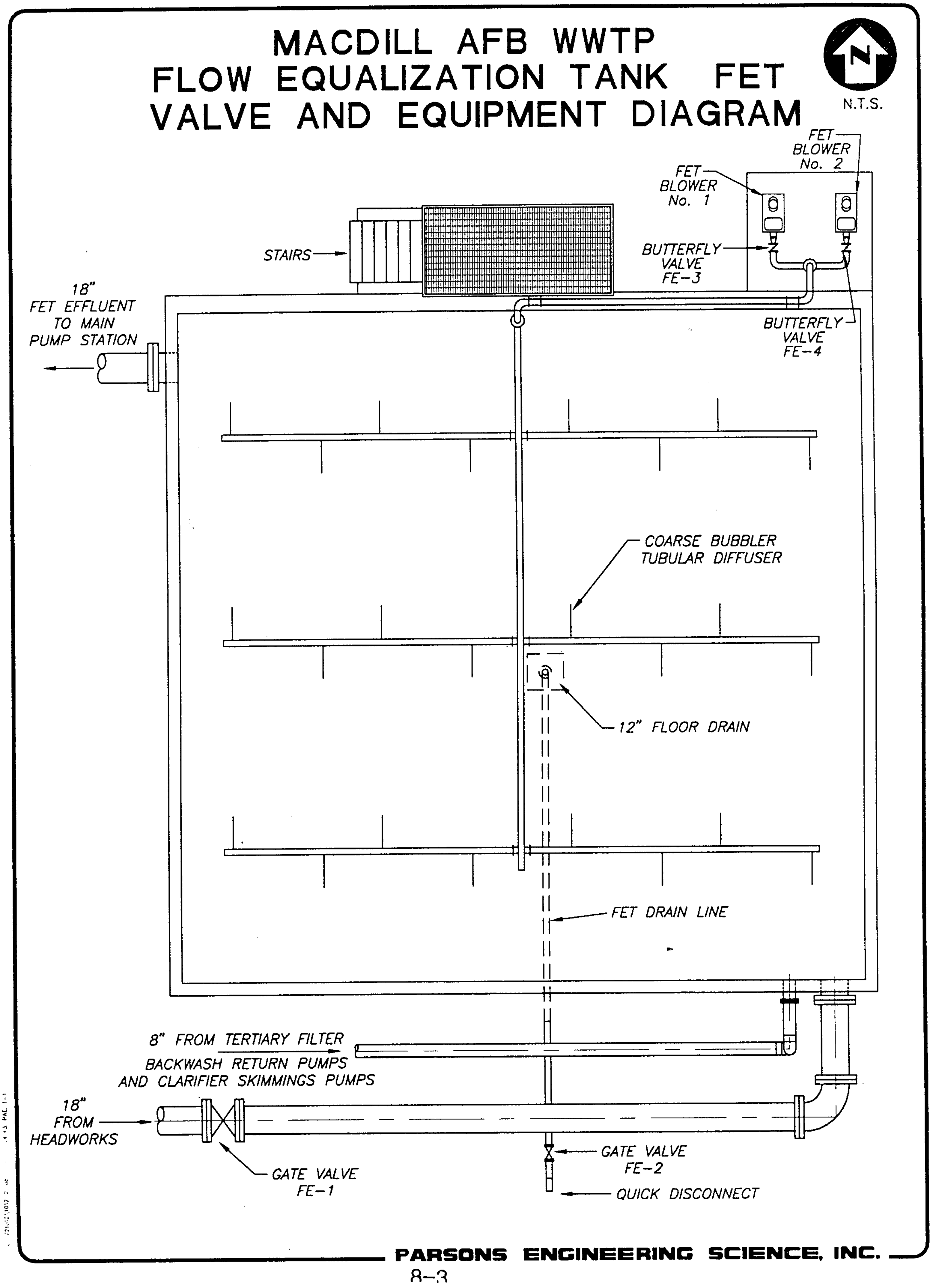
Figure 8.2



MACDILL AFB WWTP
FLOW EQUALIZATION TANK FET
VALVE AND EQUIPMENT DIAGRAM
N.T.S.
FET BLOWER No. 2
FET BLOWER No. 1
STAIRS
BUTTERFLY VALVE FE-3
18" FET EFFLUENT TO MAIN PUMP STATION
BUTTERFLY VALVE FE-4
COARSE BUBBLER TUBULAR DIFFUSER
12" FLOOR DRAIN
FET DRAIN LINE
8" FROM TERTIARY FILTER BACKWASH RETURN PUMPS AND CLARIFIER SKIMMINGS PUMPS
18" FROM HEADWORKS
GATE VALVE FE-2
GATE VALVE FE-1
QUICK DISCONNECT
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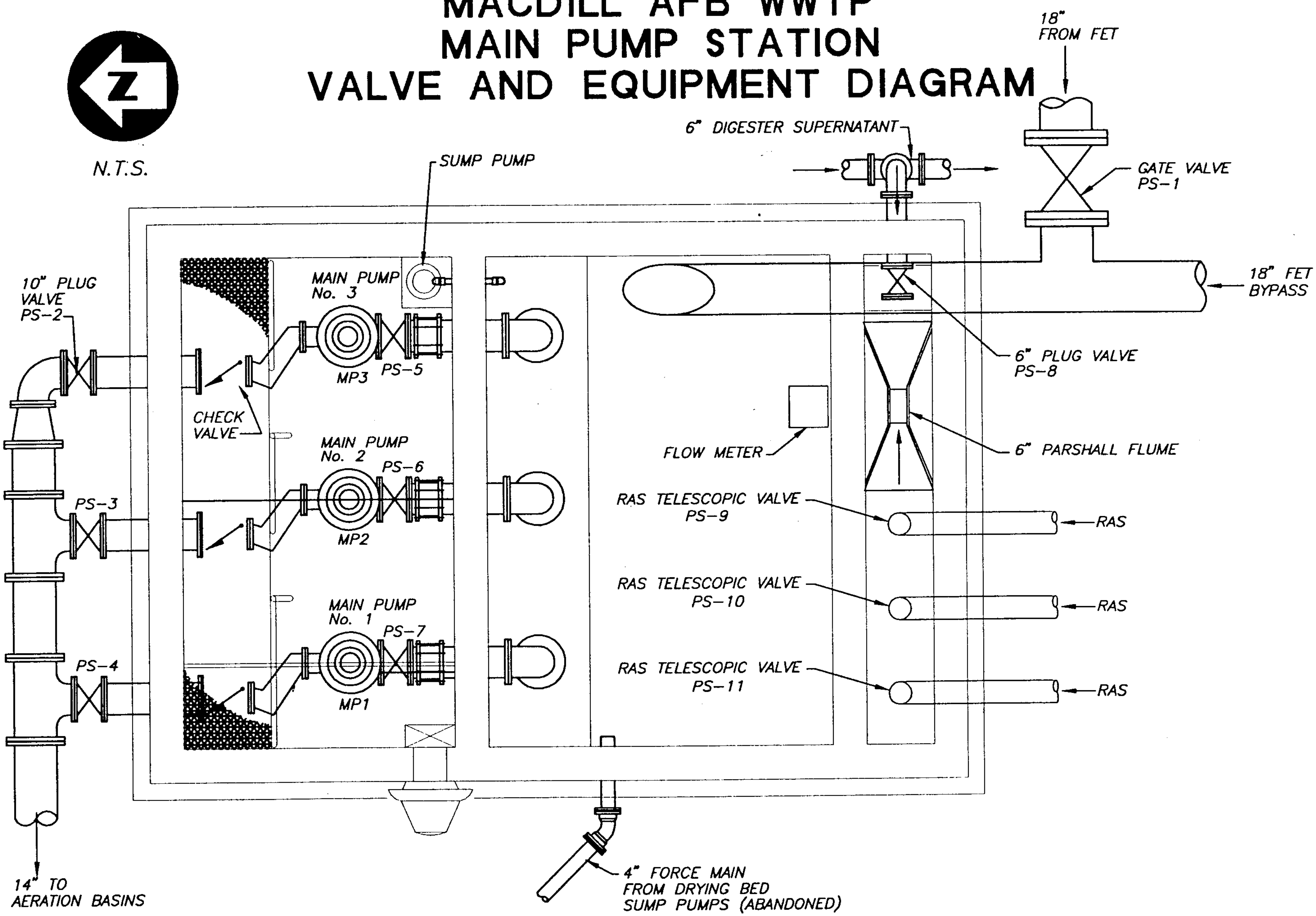
MACDILL AFB WWTP
MAIN PUMP STATION
VALVE AND EQUIPMENT DIAGRAM



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MACDILL AFB WWTP
AERATION BASINS
VALVE AND EQUIPMENT DIAGRAM

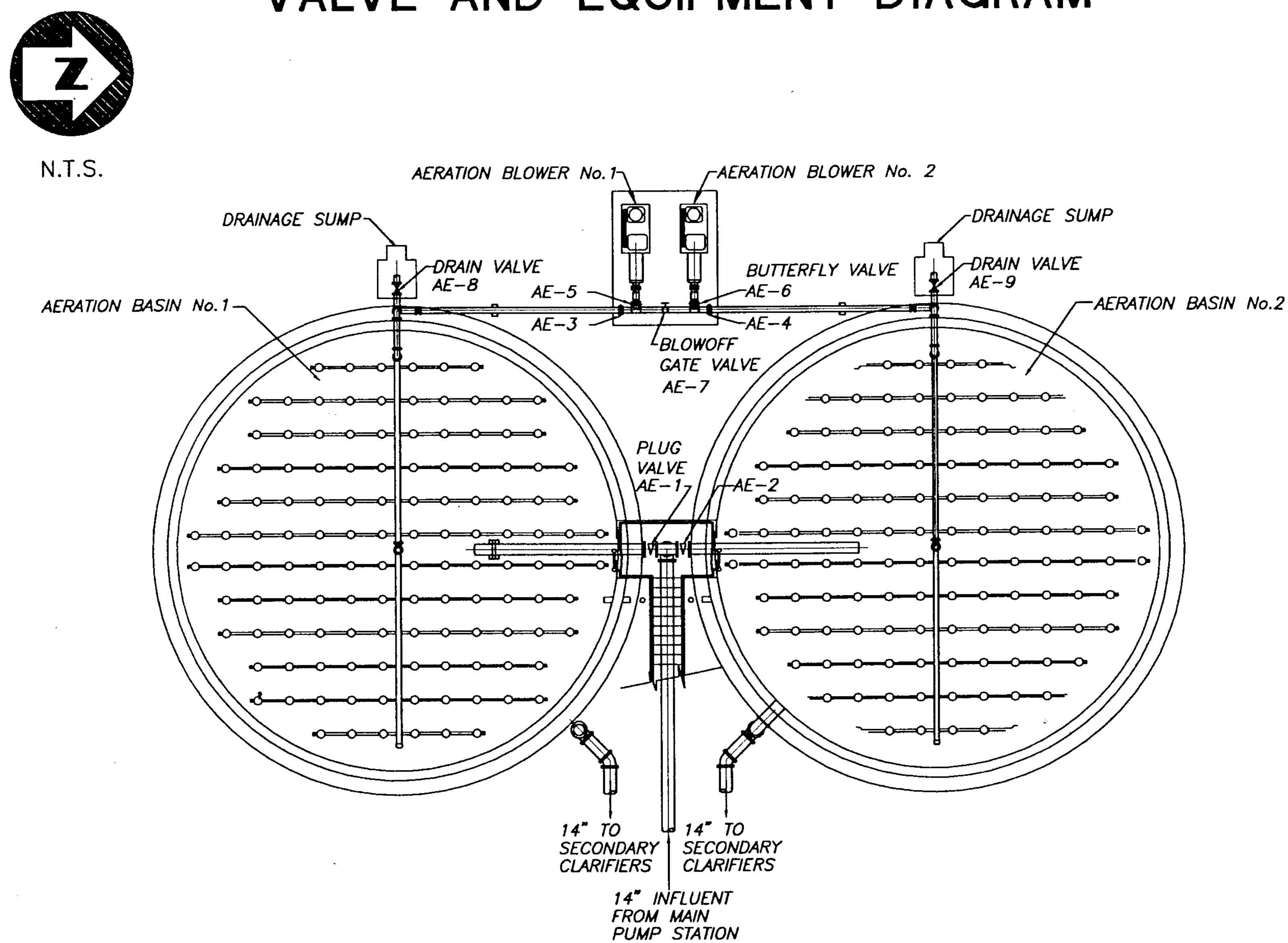

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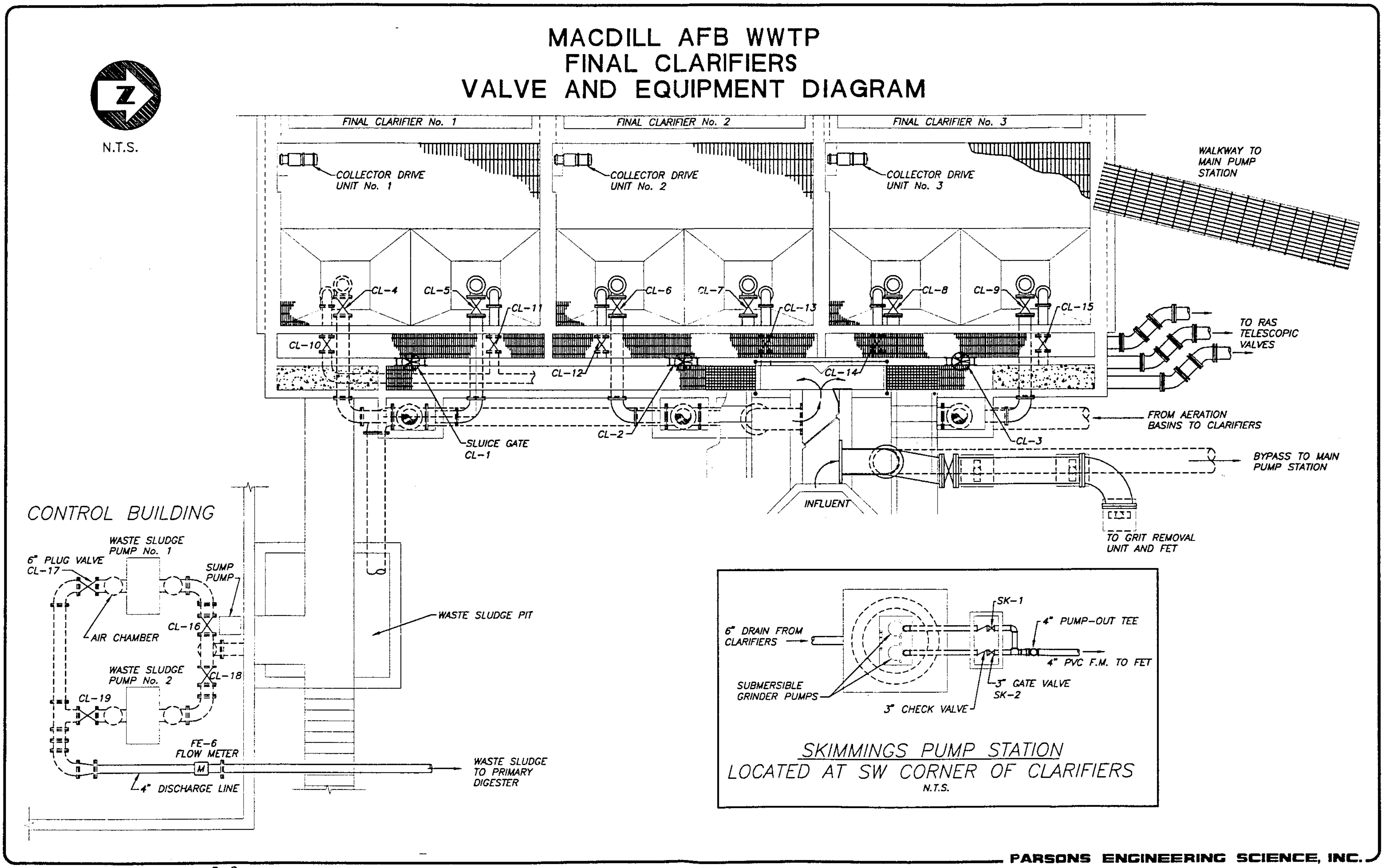
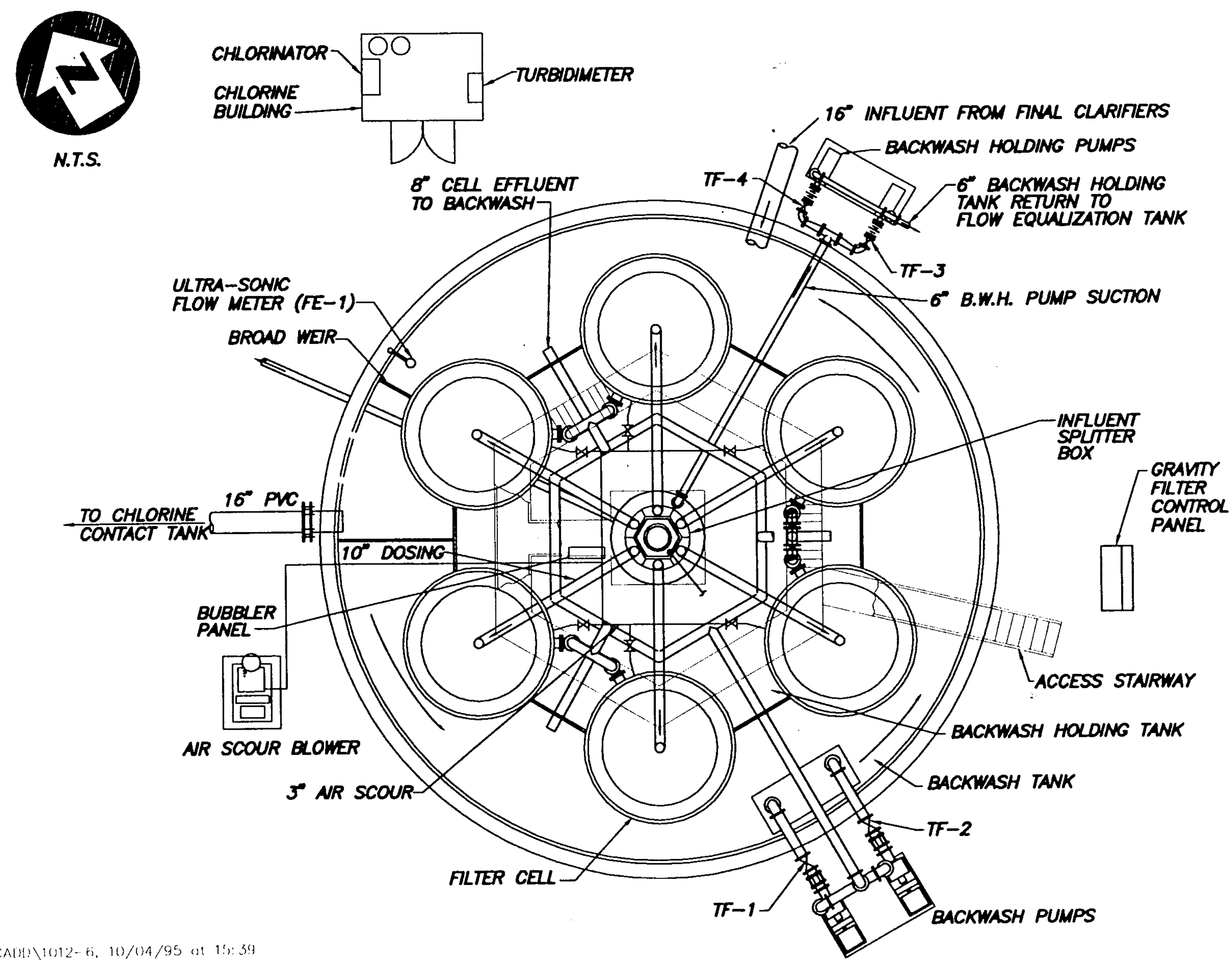
Figure 8.5


MACDILL AFB WWTP
FINAL CLARIFIERS
VALVE AND EQUIPMENT DIAGRAM
N.T.S.
FINAL CLARIFIER No. 1
FINAL CLARIFIER No. 2
FINAL CLARIFIER No. 3
COLLECTOR DRIVE UNIT No. 1
COLLECTOR DRIVE UNIT No. 2
COLLECTOR DRIVE UNIT No. 3
WALKWAY TO MAIN PUMP STATION
CL-4
CL-5
CL-6
CL-7
CL-8
CL-9
CL-10
CL-11
CL-12
CL-13
CL-14
CL-15
TO RAS TELESCOPIC VALVES
FROM AERATION BASINS TO CLARIFIERS
SLUICE GATE CL-1
CL-2
CL-3
BYPASS TO MAIN PUMP STATION
INFLUENT
TO GRIT REMOVAL UNIT AND FET
CONTROL BUILDING
WASTE SLUDGE PUMP No. 1
6" PLUG VALVE CL-17
SUMP PUMP
AIR CHAMBER
CL-16
WASTE SLUDGE PIT
WASTE SLUDGE PUMP No. 2
CL-18
CL-19
FE-6 FLOW METER
4" DISCHARGE LINE
WASTE SLUDGE TO PRIMARY DIGESTER
SK-1
4" PUMP-OUT TEE
6" DRAIN FROM CLARIFIERS
4" PVC F.M. TO FET
SUBMERSIBLE GRINDER PUMPS
3" GATE VALVE SK-2
3" CHECK VALVE
SKIMMINGS PUMP STATION
LOCATED AT SW CORNER OF CLARIFIERS
N.T.S.
PARSONS ENGINEERING SCIENCE, INC.

MACDILL AFB WWTP
TERTIARY FILTERS
VALVE AND EQUIPMENT DIAGRAM



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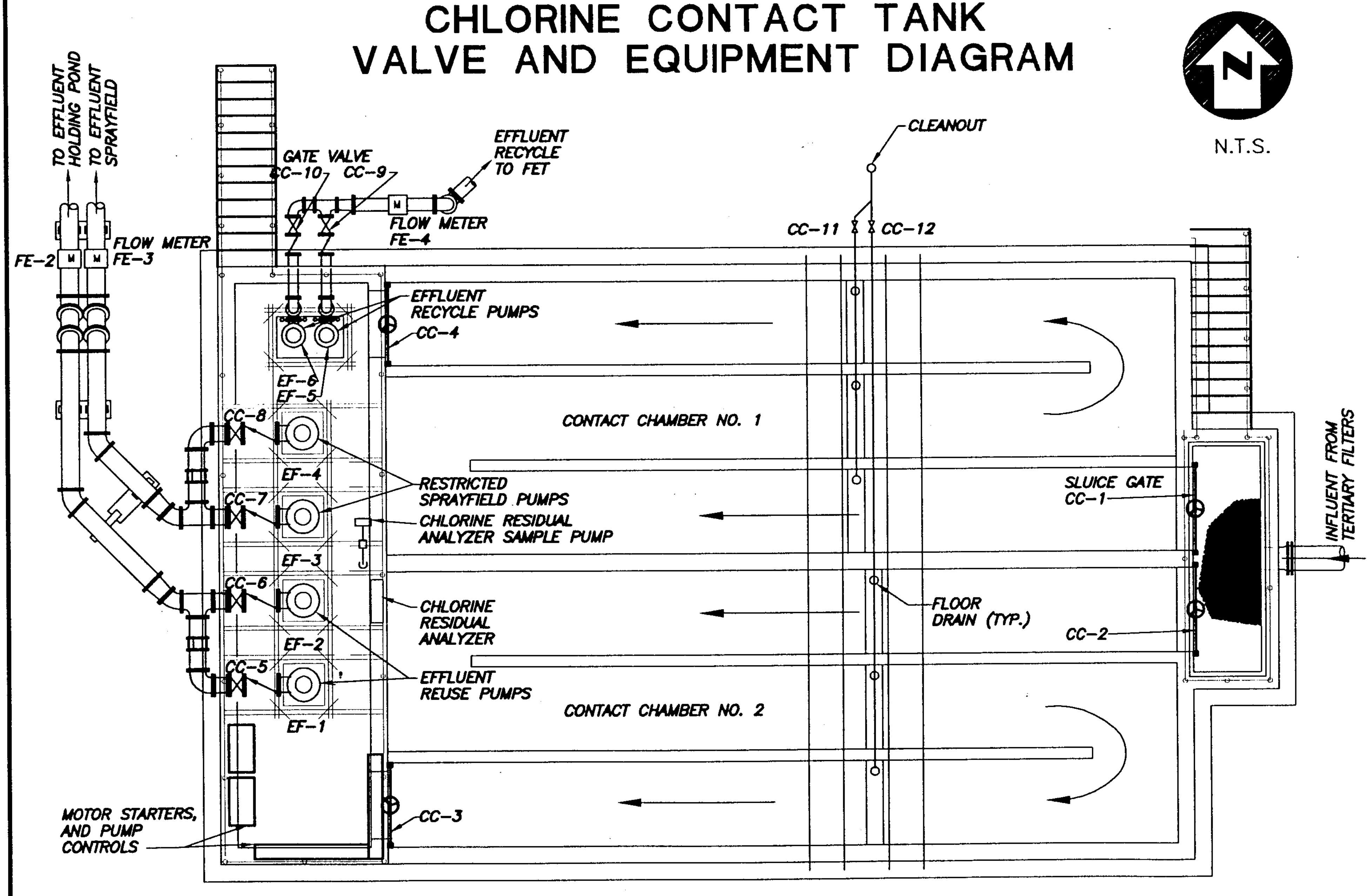
MACDILL AFB WWTP
CHLORINE CONTACT TANK
VALVE AND EQUIPMENT DIAGRAM



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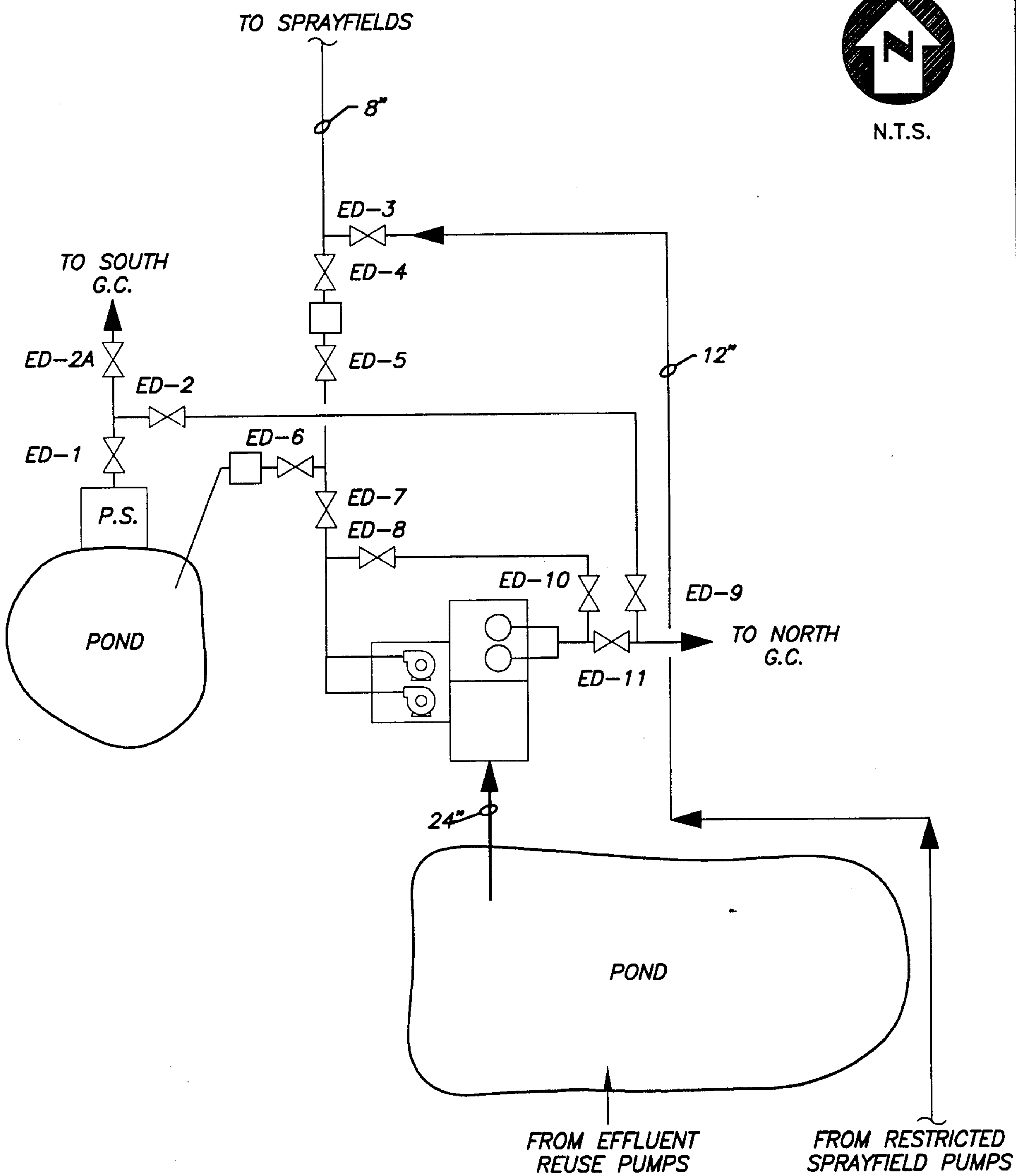
MACDILL AFB WWTP EFFLUENT DISPOSAL VALVE AND EQUIPMENT DIAGRAM



MACDILL AFB WWTP EFFLUENT SPRAYFIELDS VALVE AND EQUIPMENT DIAGRAM

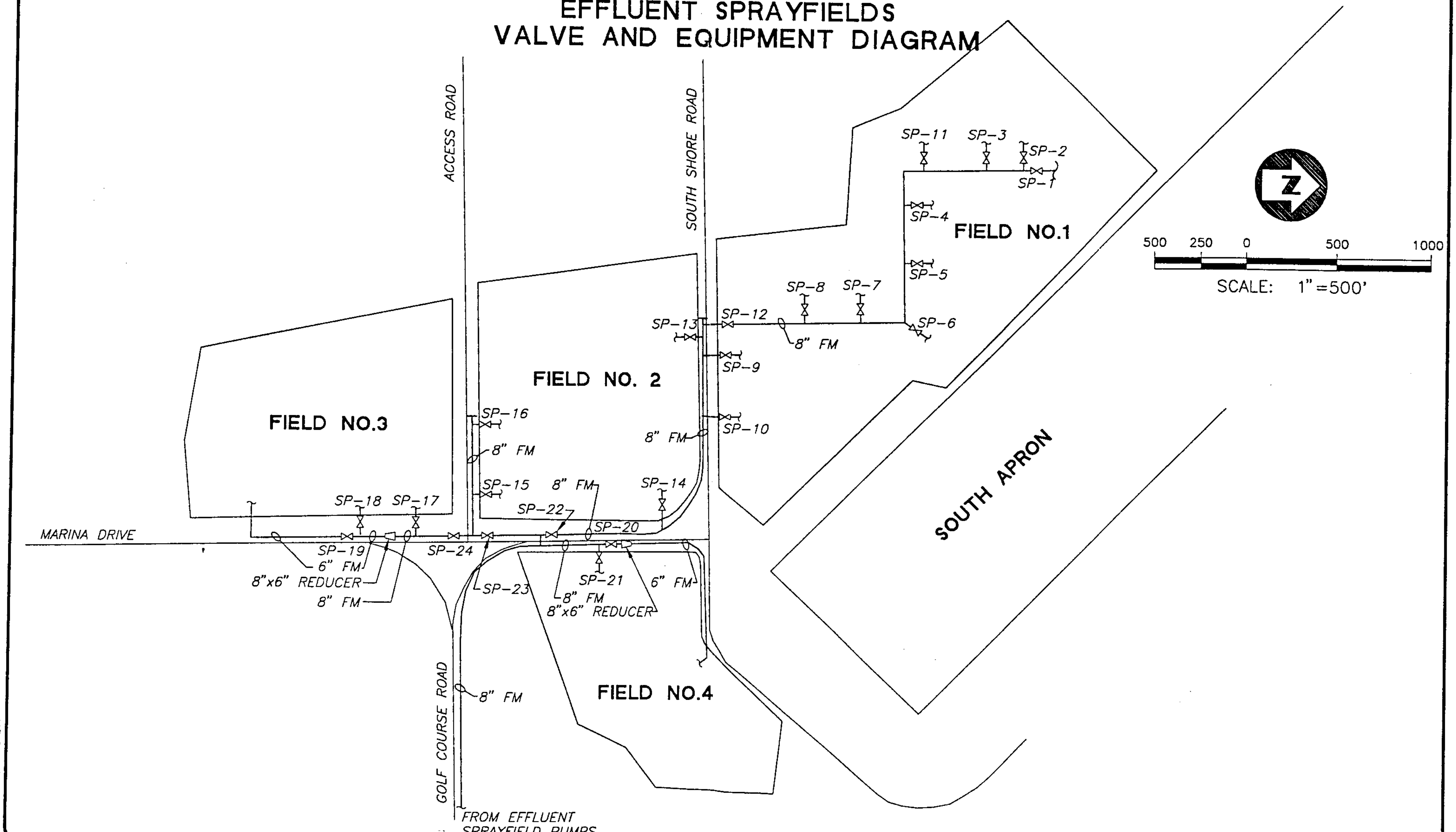


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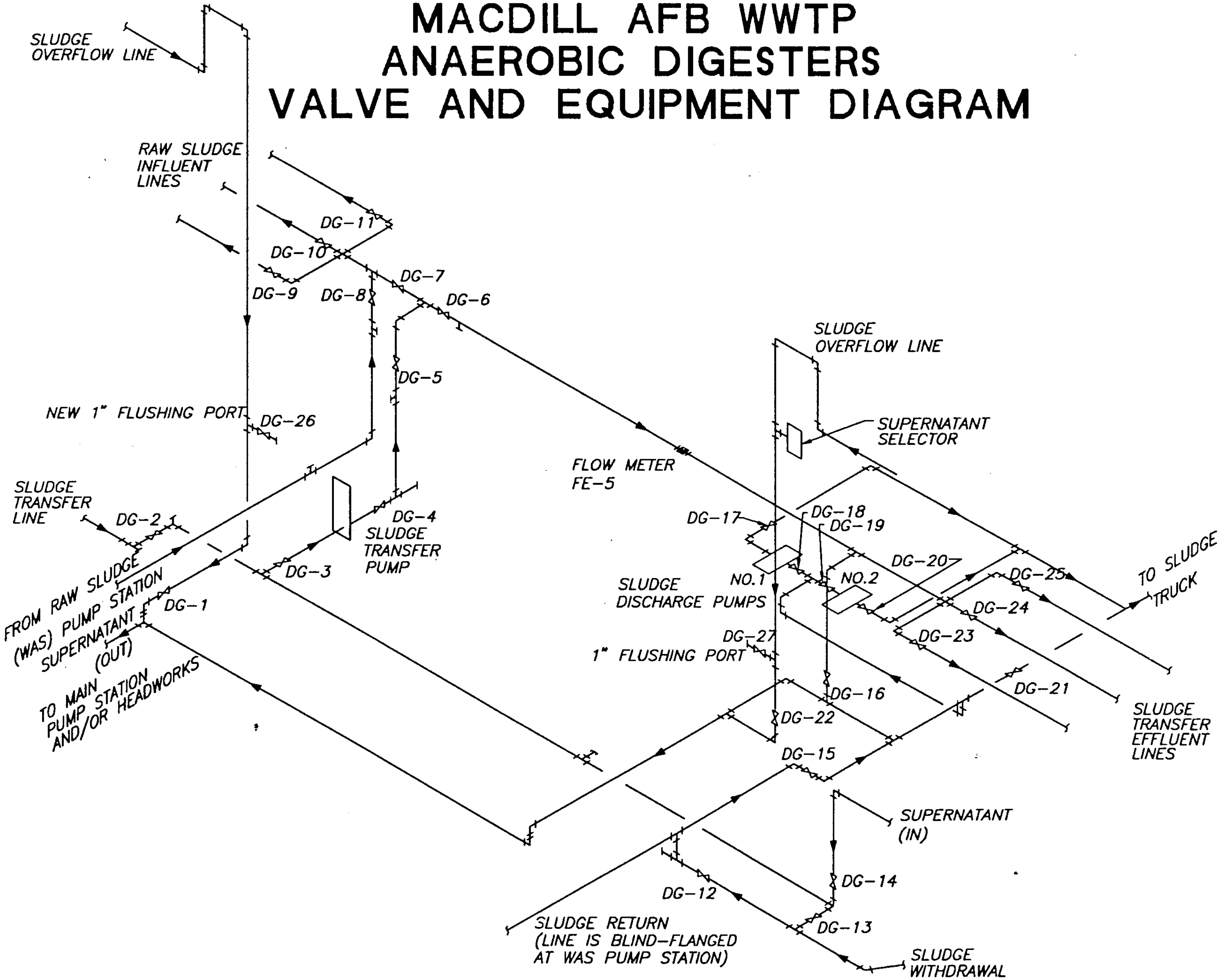
Figure 8.10

MACDILL AFB WWTP ANAEROBIC DIGESTERS VALVE AND EQUIPMENT DIAGRAM



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8.2 GENERAL STANDARDS OF PERFORMANCE

In addition to the standard operating procedures contained in Tables 8.1 through 8.10, the treatment plant operators should adhere to the following general standards of performance:

1. All incoming operators should confer with the operators on the previous shift. Special consideration should be given to operational changes made, equipment malfunctions, and out-of-the-ordinary conditions. The incoming operator will read logs and checksheets for proper operating conditions.
2. The incoming operators should immediately tour the treatment plant, observing all treatment equipment and processes.
3. Plant operators should maintain all records and logs current, neat and in ink. Unusual occurrences should be recorded in red ink to ensure proper notice by all personnel.
4. Plant operators should perform all required equipment adjustments, lubrication, and packing adjustments.
5. The operators should accomplish all sampling, analyses, pumping, and preventive maintenance as scheduled.
6. The operators should perform all necessary housekeeping to keep all areas neat and clean to enhance resource protection and safety.
7. The plant operators must report all unusual conditions to the WWTP superintendent and the incoming operator.
8. The plant operators must observe pertinent safety rules and regulations at all times.

TABLE 8.1
STANDARD OPERATING PROCEDURE
MECHANICAL BAR SCREEN

Procedure Step	Operator Checkoff
Normal Operation - Mechanical Bar Screen	
1. Observe the influent flow stream; look for unusual colors, odors, floating solids, oil, grease, or any change in normal conditions. Note changes in logbook and record time of observance.	________
2. Observe level in influent channel; high level may indicate high influent flows or a restriction downstream (i.e. bar screen clogged or inoperative).	________
3. Observe operation of mechanical bar screen and driven equipment. Check hydraulic system drive motor for unusual noise, heat or vibration. Check hydraulic system and hydraulic motors for leaks.	________
4. Remove and empty screenings trash cans as necessary. Perform required housekeeping in this area.	________
5. Perform necessary preventive maintenance on mechanical bar screen. Refer to Table 7.8.	________
6. Check manual bar screen. Rake as needed and dispose of screenings.	________
To By-Pass Mechanical Bar Screen	
1. Follow manufacturer's short-term or long-term shutdown procedures.	________
2. Remove HW-1 in entrance channel to bar screen; remove HW-2 in exit channel.	________
3. Place HW-3 in entrance channel to bar screen; place HW-4 in exit channel.	________

Note: Refer to Figure 8.1 for valve and equipment diagram.

TABLE 8.2
STANDARD OPERATING PROCEDURE
INFLUENT FLOWMETER AND GRIT REMOVAL SYSTEM

Procedure Step	Operator Checkoff
Normal Operation - Influent Flowmeter/Grit System	
1. Observe operation of influent flowmeter. Observe flow through Parshall flume for unusual conditions or blockage. Check stilling well.	________
2. Perform necessary preventive maintenance on Parshall flume and influent flowmeter. Refer to Table 7.9.	________
3. Check operation of grit chamber. Check drive motor, gear reducer, and grit pump for unusual noise, heat, or vibration.	________
4. Observe operation and condition of grit pump and grit screw classifier during operation. Observe amount of grit collected.	________
5. Perform necessary preventive maintenance on grit collector system. Refer to Table 7.10.	________
6. Check entire system for rust or corrosion. Note findings.	________
7. Gate valve settings for normal operation. CLOSED: HW-6 OPEN: HW-7	________
8. Remove and empty grit trash cans as necessary. Perform required housekeeping in this area.	________
9. Collect samples as required. See Chapter 4, Sampling Schedule.	________
To By-Pass Grit Chamber and Flow Equalization Tank	
1. Open HW-6.	________
2. Close HW-7.	________
3. Stop grit removal system.	________

Note: Refer to Figure 8.1 and 8.3 for valve and equipment diagrams.

TABLE 8.3
STANDARD OPERATING PROCEDURE
FLOW EQUALIZATION TANK

Procedure Step	Operator Checkoff
Normal Operation	
1. Observe bubble and mix pattern in equalization tank. Look for dead spots or isolated areas of large bubbles and excessive mixing. Note observations and report to supervision.	______
2. Check level in basin. Observe if water is flowing from filter backwash holding basin/skimmings pump station.	______
3. Check operation of equalization tank blowers. Check for unusual noise, heat, or vibration. Check position of discharge valve and discharge pressure relief valve. Check discharge pressure.	______
4. Perform necessary preventive maintenance on blowers. Manually alternate blowers weekly. Refer to Table 7.11.	______
5. Valve settings for normal operations are as follows: OPEN: FE-1 CLOSED: FE-2	______
6. Butterfly valves FE-3 and FE-4 are open or closed depending on the blower currently operating. Never operate blower against a closed valve.	______
To Bypass Equalization Tank and Grit System	
1. Open HW-6.	______
2. Close HW-7.	______
3. Stop operation of grit collection system.	______
4. Do not stop air flow to equalization basin unless tank level is below diffusers.	______
To Drain Equalization Tank	
1. Make arrangements for connecting a pump to the quick disconnect. Route pump discharge hose to the headworks.	______
2. Open drain valve FE-2.	______

Note: Refer to Figure 8.2 for valve/equipment diagram.

TABLE 8.4
STANDARD OPERATING PROCEDURE
MAIN PUMP STATION

Procedure Step	Operator Checkoff
Normal Operation	
1. Valve settings for normal operation: OPEN: PS-1, PS-2, PS-3, PS-4, PS-5, PS-6, PS-7 CLOSED: PS-8	________
2. Check pump control settings at motor control centers atop structure for proper settings. Record settings.	________
3. Check position of telescopic valves (PS-9, PS-10, PS-11). Adjust if necessary. Record settings.	________
4. Check pumps and drive motors for unusual noise, heat, or vibration.	________
5. Check operation of sump pump.	________
6. Observe operation of RAS flowmeter and check stilling well. Observe flow of water through Parshall flume.	________
7. Observe condition of wet well and floats for pump controller. Clean floats of debris if necessary.	________
8. Perform necessary preventive maintenance on pumps and motors. Refer to Table 7.12.	________

Note: Refer to Figure 8.3 for valve and equipment diagram.

TABLE 8.5
STANDARD OPERATING PROCEDURE
AERATION BASINS

Procedure Step	Operator Checkoff
Normal Operation	
1. Ensure that all aeration basin flow and air distribution valves are open: AE-1 AE-3 AE-2 AE-4	______
2. Butterfly valves AE-5 and AE-6 are open or closed depending on the blower currently operating. Never operate blower against a closed valve.	______
3. Observe bubble and mix pattern in aeration basins. Look for dead spots or isolated areas of large bubbles and excessive mixing. Note observations and report any unusual conditions to supervision.	______
4. Observe the mixed liquor in each aeration basin. Note the color, odor, and type of surface foam.	______
5. Run dissolved oxygen (DO) tests using the field DO meter and probe. Maintain a dissolved oxygen content of 2.0 mg/l at all locations. If DO levels are below 2.0 mg/l, notify the plant supervisor.	______
6. On a monthly basis, run a complete dissolved oxygen profile in the aeration basins.	______
7. Collect samples for mixed liquor suspended solids (MLSS), mixed liquor volatile suspended solids (MLVSS), and 30 minutes settleable solids each day.	______
8. Utilize MLSS and MLVSS data to analyze process parameters such as food to microorganism ratio (F/M) and sludge retention time (SRT) and to make appropriate process adjustments each day. Process data should be plotted on trend charts.	______
9. Calculate sludge wasting rates daily to maintain a SRT of between 4-6 days.	______
10. Perform the required preventive maintenance on the aeration basins and blowers. Manually alternate blowers weekly. Refer to Tables 7.13 and 7.14.	

TABLE 8.5 (Continued)
STANDARD OPERATING PROCEDURE
AERATION BASINS

Procedure Step	Operator Checkoff
To Shut Down an Aeration Basin	
1. Make arrangements for pumping from the basin drainage sump valve connection to the FET. Ensure that the correct aeration basin flow distribution valve is closed for aeration basin 1 or 2 (AE-1 or AE-2).	______
2. Increase the frequency of DO measurement to twice per shift for the basin remaining in service.	______
3. Open the appropriate aeration basin drain valve AE-8 or AE-9 and slowly pump contents to the aeration basin in service.	______
4. Closely monitor secondary clarifier effluent settleable solids and sludge blanket depth during the draining process. Make the necessary adjustments in the sludge return rates to reduce sludge blanket depths.	______
5. Maintain air flowing to the basin being shutdown until basin level has dropped to below the diffusers. Monitor air rates closely to the basin remaining in service.	______
6. Finish draining basin and wash down diffusers, piping, all other equipment and tank surfaces.	______

Note: Refer to Figure 8.4 for valve and equipment diagram.

TABLE 8.6
STANDARD OPERATING PROCEDURE
FINAL CLARIFIERS

Procedure Step	Operator Checkoff
Normal Operation	
1. Ensure flow is being evenly split between clarifiers. Adjust sluice gates CL-1, CL-2 and CL-3 as necessary.	________
2. Observe operation of the secondary clarifier drive units. Look for leaks and check for unusual noises, vibrations, or abnormal operating temperatures of gear reducer and motor.	________
3. Observe surface of clarifier for unusual accumulation of foam, scum or solids. Record observations and correlate to aeration basin operating conditions.	________
4. Perform sludge blanket depth measurements using the sludge judge once per shift as a minimum. Use data to adjust RAS rates.	________
5 Adjust RAS gravity-flow rates by adjusting the telescopic valves PS-9, PS-10 or PS-11 at the Main Pump Station. Lowering the telescopic valves increases the RAS rates. See Figure 8.3.	________
6. Collect samples as required. See Chapter 4, Sampling Schedule.	________
7. Perform required preventive maintenance. Refer to Table 7.15.	________
To Waste Sludge	
1. Open valve CL-4 to allow sludge to flow to the waste sludge hopper and thence to the waste sludge pit. Repeat this process for valves CL-5 through CL-9. Refer to Figure 8.5.	________
2. Ensure that the suction and discharge valve for the selected WAS pump are open (see Figure 8.5): WSP-1: CL-16, CL-17 WSP-2: CL-18, CL-19	________
4. Open the selected digester inlet valve, (DG-8 and either DG-9, DG-10 or DG-11). See Figure 8.10.	________
5. Start the sludge pump and run for the calculated time for that day's required sludge wasting to the primary digester.	________
6. Turn off sludge pump and close valves at the WAS pump station and digester.	________
7. Perform required preventive maintenance. Refer to Table 7.17.	

TABLE 8.6 (Continued)
STANDARD OPERATING PROCEDURE
FINAL CLARIFIERS

Procedure Step	Operator Checkoff
To Remove Scum	
1. Ensure that the skimmings pump station is operational.	______
2. Rotate the skimmer pipe for each clarifier to allow scum to flow to the skimmings pump station.	______
3. Perform required preventive maintenance for the skimmings pump station. Refer to Table 7.16.	______
To Remove a Clarifier From Service	
1. At the final clarifier inlet trough, close the sluice gate (CL-1, CL-2 or CL-3) to the unit to be taken out of service.	______
2. Allow RAS system to operate until head pressure is equalized. Allow rake system to continue to operate.	______
3. Monitor sludge blanket depth in clarifiers remaining in service. Adjust telescopic valves if necessary.	______
4. Close the appropriate RAS valve pairs (CL-10 through CL-15) for the clarifier being removed from service. Alternately, raise the telescopic valve for the clarifier being drained to its highest position to prevent backflow of RAS into the clarifier. Operate WAS valves to remove sludge from the clarifier hopper.	______
5. Make arrangements to pump from the clarifier to the headworks. Dewater the clarifier and stop rake system.	______
6. Hose down clarifier when dewatered to remove sludge and scum deposits.	______
7. Perform required inspections, repairs, and maintenance. Refer to Table 7.15.	______
8. Open appropriate RAS valves (CL-10 through CL-15). Resume flow into clarifier by opening sluice gate. Rebalance flows to clarifiers.	______

NOTE: See Figures 8.3, 8.5, and 8.10 for valve and equipment diagrams.

TABLE 8.7
STANDARD OPERATING PROCEDURE
TERTIARY FILTERS

Procedure Step	Operator Checkoff
Normal Operation - All Filter Cells in Operation	
1. Normal operation of the filters is in "Automatic" mode.	______
2. Observe the operation of the dosing and backwash operations.	______
3. Check backwash pumps and backwash holding pumps and motors for unusual leaks, noise, heat or vibrations.	______
4. Perform required preventive maintenance. Refer to Table 7.18.	______
Manual Backwash of any Filter Cell from Control Panel	
1. Open the backwash manifold valve to selected filter cell.	______
2. Close the dosing manifold valve to the selected filter cell.	______
3. Turn on air scour; allow to run approximately one (1) minute. Turn off air scour. Allow media to settle for at least 30 seconds prior to backwashing.	______
4. Ensure that the appropriate discharge valve for the intended backwash pump is open (either TF-1 or TF-2). Observe backwash operation.	______
5. Backwash filter for a total of 5 minutes or until backwash water is clear. Adjust wash time as needed. Turn off backwash pump. Allow filter to settle for one (1) minute.	______
6. Open dosing manifold valve and close backwash manifold valve.	______
7. Filter is now back on line.	______

Note: Refer to Figure 8.6 for valve and equipment diagram.

TABLE 8.8
STANDARD OPERATING PROCEDURE
CHLORINATION

Procedure Step	Operator Checkoff
Normal Operation	
1. Ensure that the influent and effluent sluice gates are in the correct positions for the chlorine contact chamber in service. Contact Chamber No. 1 In Service: Open CC-1, CC-4; Closed CC-2, CC-3 Contact Chamber No. 2 In Service: Open CC-2, CC-3; Closed CC-1, CC-4	______
2. Check chlorine feed system during each shift. Ensure correct chlorine feed rate at rotometer. Check automatic chlorine analyzer, pH and turbidimeters during each shift.	______
3. Check for chlorine leaks at chlorinators and cylinder connections.	______
4. Record the chlorine cylinder weight daily.	______
5. Perform cleaning procedure daily using 50% H_2SO_4 to ensure chlorine residual analyzer sensor is clean.	______
6. Perform required preventive maintenance. Refer to Table 7.19.	______
Chlorine Contact Tank	
1. Normally, only one (1) basin is used at a time. CC-1 and CC-4 should be open for operation of the North basin; CC-2 and CC-3 should remain closed. Reverse this procedure for operation of the South basin. Refer to Figure 8.7.	______
2. Chlorine residual is measured automatically by a sample pump and chlorine residual analyzer at the western end of the contact basin. Make feed rate adjustments to maintain chlorine residual of 1.0 mg/l at the sampling point for the required high level disinfection.	______
3. Collect effluent samples as required. See Chapter 4.	______
4. Perform required preventive maintenance. Refer to Table 7.20.	______
To Drain Chlorine Contact Basin	
1. Isolate basin by closing appropriate inlet and outlet sluice gates (CC-1 and CC-4 or CC-3 and CC-2).	______
2. Operate the effluent recycle pumps (EF-5 and EF-6) to lower the basin as much as possible.	______
3. Make arrangements to provide a sump pump to completely dewater the chamber. Route the pump discharge hose to the alternate contact basin.	

TABLE 8.8 (Continued)
STANDARD OPERATING PROCEDURE
CHLORINATION

Procedure Step	Operator Checkoff
Effluent Pump Station	
1. Ensure the following discharge valves are OPEN: CC-5, CC-6, CC-7, CC-8, CC-9 and CC-10.	______
2. Check the operation of the pump station on each shift. Respond immediately to high wet well alarm.	______
3. Check the pumps that are running for unusual noise, vibration, or temperature of motor or bearings.	______
4. Ensure proper housekeeping is maintained. Clean up spills of water, lubricants, etc.	______
5. Perform required preventive maintenance on pumps. Refer to preventive maintenance schedules. See Table 7.21.	______

Note: Refer to Figure 8.7 for a valve and equipment diagram.

TABLE 8.9
STANDARD OPERATING PROCEDURE
EFFLUENT DISPOSAL/SPRAYFIELDS

Procedure Step	Operator Checkoff
Normal Operation	
1. Check holding pond level and sprayfield pump float controls at old chlorine contact tank (located at Northwest corner of pond). Minimum pond freeboard is 2-feet.	______
2. Check pumps (two centrifugal, two vertical turbine) and drive motors for any unusual noise, vibration or temperature. The vertical turbine pumps are maintained by golf course personnel - report any problems to golf course maintenance.	______
3. Check valve settings (see Figure 8.8):	
Normally Open: ED-3, ED-4, ED-7 — Open or Closed* Golf Course Controlled: ED-1, ED-2A, ED-2, ED-5, ED-6, ED-8, ED-9, ED-10, ED-11	
*Check with Golf Course personnel before changing their valve settings.	______
4. Check sprayfields for spray pattern and mowing requirements. Rotate sprayfields as required. See Figure 8.9.	______
5. Perform required preventive maintenance. Refer to Table 7.25.	______

Valve settings for step 3:

Normally Open	Open or Closed* Golf Course Controlled
ED-3	ED-1
	ED-2A
ED-4	ED-2
ED-7	ED-5
	ED-6
	ED-8
	ED-9
	ED-10
	ED-11

Note: Refer to Figures 8.8 and 8.9 for a valve and equipment diagrams.

TABLE 8.10
STANDARD OPERATING PROCEDURE
ANAEROBIC DIGESTERS

Procedure Step	Operator Checkoff
Normal Operation	
1. Observe digester piping, valves and pumps for leaks. Check pumps and motors for any unusual vibration, noise or temperature. Observe mixing pattern in primary digester.	____
2. Observe digesters for accumulation of excess scum. Observe levels in primary and secondary digesters. Transfer sludge from primary to secondary digester as required for wasting.	____
3. Collect samples as required to determine percent reduction of volatile matter in the digester. Target reduction is 40%.	____
4. Perform required preventive maintenance. Refer to Tables 7.22 and 7.23 for preventive maintenance schedules.	____
To Transfer Sludge from Primary to Secondary Digester	
1. Ensure the following valve positions (see Figure 8.10): Open: DG-2, DG-3, DG-4, DG-5, DG-6, DG-23 (or DG-24 or DG-25) Closed: DG-7, DG-13, DG-16	____
2. Record the starting reading from the flowmeter totalizer.	____
3. Start the sludge transfer pump. Monitor levels in both primary and secondary digesters.	____
4. Stop pump when transfer is complete. Return valves to closed position.	____
To Pump Digested Sludge to Truck	
1. Sample the secondary digester and analyze for volatile solids. Determine the percent reduction of volatile solids using the following formula: $P = \frac{(IN - OUT)}{IN - (IN \times OUT)} \times 100\%$ where: IN = % volatile solids in feed sludge (WAS) OUT = % volatile solids in the secondary digester P = % reduction in volatile solids The permit requires a minimum 38% reduction in volatile solids.	____
2. Make arrangements with contract sludge hauler.	____

TABLE 8.10 (Continued)
STANDARD OPERATING PROCEDURE
ANAEROBIC DIGESTERS

Procedure Step	Operator Checkoff

Records

1. Record amount of sludge wasted to digestors (WAS), amount of sludge transferred from primary to secondary digestor and amount of sludge to trucks. Record date and time of each transfer of sludge.

3. When empty sludge truck is positioned, ensure the following valve positions:

To Use Pump No. 1

Open	Closed
DG-12	DG-13
DG-15	DG-16
DG-17	DG-21
DG-18	DG-19
	DG-20

To Use Pump No. 2

Open	Closed
DG-12	DG-13
DG-15	DG-16
DG-19	DG-21
DG-20	DG-17
	DG-18

____

4. Start the selected sludge pump and transfer sludge to the truck. Verify that the truck is being filled. _______________

5. After filling the truck, stop the pump and return all valves to their closed position. _______________

To Remove a Digester from Service

1. Follow one of the above procedures for pumping sludge to the other digester in order to empty the digester. _______________

2. Wash down all interior equipment in digester and perform complete inspection of interior walls, floors and piping. _______________

3. Perform required preventive maintenance. Refer to Table 7.22 and 7.23. _______________

Note: Refer to Figure 8.10 for a valve and equipment diagrams.

CHAPTER 9
RECORDS AND REPORTING

CHAPTER 9
RECORDS AND REPORTING

9.1 RECORDS AND REPORTING

9.1.1 Daily Operating Logs

A comprehensive record-keeping system is essential to the operation of the MacDill AFB WWTP. Daily operating records are the central component of any record-keeping system.

Daily observation of all components in the WWTP system is necessary to ensure continued successful operation. The operators should utilize both a journal type logbook and a plant operational log.

The plant operational log will contain routine information that is entered by each shift. All shifts are responsible for checking off and recording the following data:

- Bar screen rakings.
- Sludge withdrawn from digester.
- Digester supernatant withdrawn.
- Shift maximum influent/effluent pH.
- Flow meter readings from each shift.
- Chlorine usage and chlorine residuals
- Sulfur dioxide usage.
- Aeration basin operating conditions.
- Secondary clarifier operating conditions.
- Personnel on duty.
- Equipment problems and unusual operating conditions.

- Lift station operating conditions.

9.1.2 Monthly Operating Logs

The wastewater treatment plant operators are required to prepare monthly operating logs, specifically Air Force Forms 1462, Water Pollution Control Utility Operating Log (General), and 1463 Water Pollution Control Plant Operating Log (Supplementary). Information required for these forms is drawn from daily plant operating logs and laboratory data sheets. Some of the important data required for these logs include the following:

- Influent temperature
- Influent pH
- Influent settleable solids
- Plant effluent settleable solids
- Plant effluent DO
- Plant effluent pH
- Chlorine residual
- Plant flow
- Cl_2 weight, pounds used.

9.1.3 Monthly Reports to Regulatory Agencies

Under regulatory requirements, the WWTP operators are required to generate monthly self-monitoring reports to the State of Florida. Data from the reports is entered on the Discharge Monitoring Report by the Supervisor of the Wastewater Treatment Plant. The reports are then submitted to the Base Environmental Compliance Chief for review and approval.

9.1.4 Laboratory Worksheets

The NPDES Permit requires that specific laboratory records (benchsheets) be maintained as part of the WWTP's self-monitoring program. These records provide the basis and validity for all analytical data produced and reported. Examples of laboratory

worksheets are provided in Appendix A. These worksheets should be periodically updated to reflect regulatory changes.

9.1.5 Sludge Disposal Records

A record of the quantity of sludge disposed of should be maintained for permit and operational documentation. Generally, the quantity of sludge produced by the wastewater treatment plant should be equal to the quantity disposed of. A record of sludge applied to the land treatment site should be maintained. A weekly and cumulative record of the gallons and pounds of dry sludge applied should be kept.

CHAPTER 10
NONDOMESTIC DISCHARGES

CHAPTER 10
NONDOMESTIC DISCHARGES

10.1 NONDOMESTIC DISCHARGES

In addition to the domestic wastewater treated at the MacDill AFB WWTP, a small number of nondomestic discharges contribute to the load on the plant. It was estimated that less than 1 percent of the influent flow to the WWTP was from nondomestic sources.

10.1.1 Sources of Nondomestic Discharges

Based on discussions with plant personnel and maintenance personnel at facilities along the flight line, industrial discharges to the wastewater collection system were limited to oils and greases, which are pretreated by oil/water separators. Oil/water separators are designed to remove lighter-than-water substances such as oil, fuel, and grease from various wastewater discharges. The oily phase is skimmed from the water surface and accumulates in a sump associated with each oil/water separator for periodic pick-up and disposal by a private contractor. Other heavier-than-water or dissolved contaminants potentially present in the water discharged to an oil/water separator, such as solvents, cannot be removed by this process. The water phase from the separators is then discharged to the base sanitary sewer system, or in the case of the isolated separators, the discharge goes to the storm drainage system, and is not treated further. This storm drainage eventually discharges into the bay. Thirty-nine (39) oil/water separators, seven of which are known to discharge to the storm drainage system, are located on the Base. Base oil/water separators are listed in Table 10.1.

Table 10.1 Oil/Water Separators

Facility No.	Facility	Point of Discharge
H-1	Inflight Kitchen	Sanitary Sewer
H-4	Wheel and Tire	Sanitary Sewer
H-4	Propulsion	Sanitary Sewer
8	Fire Truck Maint.	Sanitary Sewer
25	Photo Lab	Sanitary Sewer
33	CE	Sanitary Sewer
178	Transportation	Sanitary Sewer

Table 10.1 Oil/Water Separators (Cont'd)

Facility No.	Facility	Point of Discharge
305	Auto Hobby	Sanitary Sewer
374	Reprographics	Sanitary Sewer
500	Transportation	Drainage Ditch
500	Transportation	Drainage Ditch
518	Aircraft Washrack	Sanitary Sewer
527	Mobile Maint.	Sanitary Sewer
552	AGE	Sanitary Sewer
555	AAFES Service Sta.	Sanitary Sewer
701	37AEG	Sanitary Sewer
847	USCENTCOM	Sanitary Sewer
847	USSOCOM	Sanitary Sewer
847	USSOCOM	Sanitary Sewer
860	JCSE Washrack	Sanitary Sewer
862	JCSE	Sanitary Sewer
864	Pest. Washrack	Drainage Ditch
1050	Harvest Eagle	Drainage Ditch
1051	Fuels Mobility	Unknown
1051	Fuels Mobility	Unknown
1061	Fuel Truck Maint.	Unknown
1065	Corrosion Cont.	Sanitary Sewer
1070	Hydrazine Bldg.	Drainage Ditch
1071	Fuels Barn	Sanitary Sewer
1119	Fuels Storage	Drainage Ditch
1121	Fuels Storage	Drainage Ditch
1144	Asbestos Office	Unknown
1152	Wash Area	Unknown
1188	Fire Training Pit	Sanitary Sewer
1194	Hush House	Sanitary Sewer
1195/1153	Hush House	Sanitary Sewer

Table 10.1 Oil/Water Separators (Cont'd)

Facility No.	Facility	Point of Discharge
1886	290 JCSS	Sanitary Sewer
1886	290 JCSS	Sanitary Sewer
1886	290 JCSS	Sanitary Sewer

Although there currently appears to be only a small potential for nondomestic industrial waste entering the sanitary sewer system, plant personnel have indicated that discharges from on-base have created problems with WWTP operation in the past. A thorough, systematic industrial survey should be performed on the base to ensure that all sources of industrial waste and waste handling practices are identified. From this type of information, a contingency plan for identifying and responding to industrial wastewater problems at the WWTP can be developed.

10.1.2 Importance of Pretreatment Programs for Nondomestic Discharges

Pretreatment is any operation or series of operations that change the characteristics of a nondomestic discharge to make it more acceptable for subsequent treatment and disposal at a wastewater treatment facility. Pretreatment programs are often necessary when nondomestic discharges contain toxic materials or other substances which could adversely affect the WWTP. Most WWTPs designed to treat domestic waste are incapable of treating toxic or concentrated nondomestic discharges. The result is that untreated nondomestic discharges may be incompatible with the WWTP.

Within a treatment plant, incompatibility may create four specific types of problems:

- Inhibition or interference with normal plant operations.
- Accumulation of heavy metals or other toxic substances.
- Pass through of organics and heavy metals.
- Undesirable effects on the sewer system or structures of the treatment plant.

The goal of any pretreatment program is to limit or eliminate problems associated with incompatibility in the WWTP. Reduction of incompatibility decreases the likelihood of plant upset and the discharge of pollutants to the environment.

The ramifications of not controlling nondomestic discharge are far-reaching. Toxic or incompatible discharge to the WWTP can lead to process upsets and violation of effluent standards. Further, the possibility of a buildup of contaminants in the sludge at the WWTP could lead to increasingly higher costs for sludge disposal. Analytical costs associated with sludge disposal could also be increased.

10.1.3 Responsibilities for Nondomestic Pollutant Generators

The primary responsibility for monitoring the activities of nondomestic discharges is with Base Civil Engineering and Bio-Environmental Section. A periodic survey of all industrial users that are tributary to the WWTP should be conducted. However, each facility manager must be constantly aware of activities in the facility that could lead to increased nondomestic discharges. Any dumps, leaks, or uncontrolled discharges should be reported immediately to the WWTP personnel so they can take appropriate action.

APPENDIX A
EXAMPLE LABORATORY RECORDS, DATA SHEETS

BIOCHEMICAL OXYGEN DEMAND
STANDARD METHODS 18th EDITION, PAGE 5-2
PROCEDURE 5210B

SAMPLE/ DATE	VOLUME (ml) SAMPLE	VOLUME (ml) SEED	INITIAL			FINAL			D.O. DROP	BOD^5 (mg/l)
			#	D.O.	DATE	#	D.O.	DATE		

G/AT663CTS/PM4/MAC/030392

FECAL COLIFORM
STANDARD METHODS, 18th EDITION, PAGE 9-60
MEMBRANE FILTER PROCEDURE 9222D

SAMPLE/ DATE	ML SAMPLE	PLATE COUNT	DILUTION FACTOR	NO./100ML	DATE/TIME SET UP	DATE/TIME READ	ANALYST

pH
STANDARD METHODS, 18th EDITION, PAGE 4-65
PROCEDURE 4500-H^+B

SAMPLE/ DATE	ZERO METER	BUFFER CHECK VALUE/READING/TEMP	DATE	SAMPLE READING/TEMP	ANALYST

SUSPENDED SOLIDS
STANDARD METHODS, 18th EDITION
(TOTAL SUSPENDED SOLIDS, PAGE 2-56, PROCEDURE 2540 D)
(VOLATILE AND FIXED SOLIDS, PAGE 2-57, PROCEDURE 2540E)

Sample					
Sample Date					
Sample Volume (ml)					
Dish No.					
Dish Residue Wt. (R)					
Dish Ignited Residue Wt. (I)					
Dish Wt. (T)					
Solids (grams) R-T					
Volatile Solids (grams) R-I					
Solids (mg/l)					
Volatile Solids (mg/l)					
Analyst/Date					

Sample					
Sample Date					
Sample Volume (ml)					
Dish No.					
Dish Residue Wt. (R)					
Dish Ignited Residue Wt. (I)					
Dish Wt. (T)					
Solids (grams) R-T					
Volatile Solids (grams) R-I					
Solids (mg/l)					
Volatile Solids (mg/l)					
Analyst/Date					

Sample					
Sample Date					
Sample Volume (ml)					
Dish No.					
Dish Residue Wt. (R)					
Dish Ignited Residue Wt. (I)					
Dish Wt. (T)					
Solids (grams) R-T					
Volatile Solids (grams) R-I					
Solids (mg/l)					
Volatile Solids (mg/l)					
Analyst/Date					

TOTAL SOLIDS
STANDARD METHODS, 18th EDITION
(TOTAL SOLIDS DRIED AT 103-105°C, PAGE 2-54, PROCEDURE 2540 B)
(VOLATILE AND FIXED SOLIDS IGNITED AT 550°C, PAGE 2-57, PROCEDURE 2540E)

Sample					
Sample Date					
Sample Volume (ml)					
Dish No.					
Weight of Dried Residue + Dish, mg (A)					
Weight of Dish & residue After Ignition, mg (B)					
Weight of Dish, mg (C)					
Total Solids, mg/l $= \frac{(A-C) \times 1000}{\text{Sample Volume, ml}}$					
Volatile Solids, mg/l $= \frac{(A-B) \times 1000}{\text{Sample Volume, ml}}$					

Sample					
Sample Date					
Sample Volume (ml)					
Dish No.					
Weight of Dried Residue + Dish, mg (A)					
Weight of Dish & residue After Ignition, mg (B)					
Weight of Dish, mg (C)					
Total Solids, mg/l $= \frac{(A-C) \times 1000}{\text{Sample Volume, ml}}$					
Volatile Solids, mg/l $= \frac{(A-B) \times 1000}{\text{Sample Volume, ml}}$					

Sample					
Sample Date					
Sample Volume (ml)					
Dish No.					
Weight of Dried Residue + Dish, mg (A)					
Weight of Dish & residue After Ignition, mg (B)					
Weight of Dish, mg (C)					
Total Solids, mg/l $= \frac{(A-C) \times 1000}{\text{Sample Volume, ml}}$					
Volatile Solids, mg/l $= \frac{(A-B) \times 1000}{\text{Sample Volume, ml}}$					

CHLORINE RESIDUAL SAMPLE

DATE COLLECTED	TIME ANALYZED	TYPE OF SAMPLE	Cl_2 PPM	LOCATION OF SAMPLE	INITIALS OF ANALYST

G/AT663CTS/PM4/MAC/030392

BOD$_5$ INCUBATOR RECORD

DATE READ	TIME READ	INCUBATOR TEMPERATURE O°C	INITIALS OF ANALYST	REMARKS

DRYING OVEN RECORD

DATE READ	TIME READ	TEMP. OF OVEN O°C	INITIAL OF ANALYST	FILTER DRYING START TIME	FILTER DRYING FINISH TIME	SAMPLE DRYING START TIME	SAMPLE DRYING FINISH TIME

G/AT863CTS/PM4/MAC/030392

LAB REFRIGERATOR RECORD

TEMP. OF REFRIGERATOR

DATE READ	TIME READ	TEMP. OF REFRIGERATOR	INITIALS OF ANALYST	REMARKS

G/AT663CTS/PM4/MAC/030392

DILUTION WATER INCUBATION RECORD

DATE READ	TIME READ	INCUBATOR TEMPERATURE O°C	INITIALS OF ANALYST	REMARKS

COMPOSITE SAMPLE RECORD

DATE COL-LECTED	BOTTLE NO.	TIME COL-LECTED	LOCATION OF SAMPLE	PARSHALL FLUME		MGD	% ERROR	FLOW METER READING	CHART RE-CORDER READING	COM-POSITE SAMPLE ML	SAMPLERS INITIALS
				INCH	FT.						

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APPENDIX B
SUGGESTED MAINTENANCE
RECORD KEEPING FORMS

PUMP DATA

PUMP: ______________________ EQUIP. NO.: ____________

LOCATION: ______________________________________

MFGR.: ________________ MODEL: ________________

SIZE: __________________ TYPE: _________________

CAPACITY: ______________________________________

MATERIAL: ______________________________________

BEARING NOS.: ___________________________________

SEAL TYPE/SIZE: _________________________________

SERIAL NO.: ____________ DATE INSTALLED: ________ COST: ________

LOCAL REP.: ____________________ PHONE: ____________

PUMP DATA CARD

MOTOR DATA

MOTOR: ____________ EQUIP. NO.: ____________

MFGR.: ____________ MODEL: ____________

HORSEPOWER: ____________ SPEED: ____________

VOLTAGE: ____________ AMPS: ____________

PHASE: ____________ HERTZ: ____________

SERVICE FACTOR: ____________ AMB. TEMP.: ____________

INSULATION: ____________ TEMP. RISE: ____________

FRAME: ____________ ENCLOSURE: ____________

BEARING NO.: ____________

SERIAL NO.: ____________ DATE INSTALLED: ________ COST: ________

MOTOR DATA CARD

EQUIPMENT DATA

UNIT: ______________________ EQUIP. NO.: __________

LOCATION: ______________________________________

MFGR.: ______________________ MODEL: __________

SIZE: ______________________ TYPE: __________

RATING HP: ______________________ CAPACITY: __________

INPUT RPM: ______________________ OUTPUT RPM: __________

SERVICE FACTOR: ______________________ RATIO: __________

OTHER DESCRIPTION: ______________________________

____

BEARING NO.: ____________________________________

SERIAL NO.: __________ DATE INSTALLED: __________ COST: __________

LOCAL REP.: ______________________ PHONE: __________

EQUIPMENT DATA CARD

EQUIP. NO.: ____________

SERVICE RECORD - A

EQUIPMENT: ____

MANUFACTURER'S MANUAL: CONTRACT ________ VOL.: ________ SECTION: ________

TASK NO.	TASK DESCRIPTION	LUBE CODE	FREQUENCY OF SERVICE

SERVICE RECORD-A (INFORMATION)

EQUIP. NO.: ____________

SERVICE RECORD - B

EQUIPMENT: ____________

TASK	DATE	INIT.	TIME	REMARKS	TASK	DATE	INIT.	TIME	REMARKS

SERVICE RECORD - B (DATA)

REPAIR RECORD

EQUIP. NO.: ____________

EQUIPMENT: ____________

MANUFACTURER'S MANUAL: CONTRACT ________ VOL: ______ SECTION: ________

DATE	MAINTENANCE WORK REQUIRED AND PARTS REPLACED	REPLACEMENT PART		INIT.	TIME
		NUMBER	COST		HOURS

REPAIR RECORD CARD

ES ENGINEERING-SCIENCE

EQUIP. NO.: ____________

MOTOR SERVICE RECORD

PRIMARY EQUIPMENT: ____________ OVERLOAD RELAY ________ SIZE ________

MANUFACTURER: ____________ HEATER NO. ______ SETTING ______ C.T. AMPS ______

HP ______ VOLTS ______ AMPS ______ STARTER ______ TYPE ______ SIZE ______

PHASE ______ HZ. ______ COIL NO. ______ VOLTAGE ______ HZ. ______

TEST DATA

DATE OF TEST	MOTOR						STARTER	CONTACT		BEARING	BRUSHES	SLIP RING	INIT.	REMARKS
	VOLTAGE	AMPERES 1	2	3	MEGGER READING	TEMP		CK.	LUB.					

MOTOR SERVICE RECORD FORM

SPARE PARTS RECORD

Order		Item			Received		Issued			Number In Stock	Inventory Date & Initial
No.	Date	Quantity	Description	Cat. No.	Date	Cost	Date	Quantity	Index No.		

SPARE PARTS RECORD FORM

SAMPLE INVENTORY CARD

STOREROOM INVENTORY CARD

Item Description -

Item No. ________

Isle No. ________

Bin No. ________

Quantity Maximum ________ Minimum ________

Reorder ________

INVENTORY INFORMATION

Quantity Used or Stocked	Date	Signed	Quantity on Hand	USAGE OR SUPPLY INFORMATION Usage - Work Order No. Supply - Purchase Order No.